Generic Robotic Workstation Module Assembly Manager (MAM) User's Guide, Version 5.0

DOCUMENT IDENTIFIER: A-MN-ELMF519-02-0000 Rev D, 15-Aug-1990

ABSTRACT: This document defines the procedure for using version 5.5 of the Module Assembly Manager (MAM) program designed for the Generic Robotic Workstation.

APPLICABILITY: The procedures defined in this document apply to all technicians and support engineers who program the Generic Robotic Workstation using MAM.

STATUS: APPROVED 15-Aug-1990; use VTX SMC for current status.

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CHAPTER 1

INTRODUCTION

The Module Assembly Manager (MAM) is a general purpose pick-and-place program designed to control the Generic Robotic Workstation developed by Small Systems Manufacturing. The program contains data bases to manage the assembly of printed-wiring boards (PWBs) and utilities that interact with the data bases. The software is written in V+™ and is executed in the Adept robot controller.

The purpose of this document is to familiarize users with the data base structure and utilities of MAM. After reading this document, readers should be able to set up the workstation, modify existing data base entities, and set up for module assembly.

EL-MF519-00 Acceptance Specification for the Generic Robotic Workstation (in process) provides procedures required for the acceptance of the workstation into manufacturing. *EL-MF519-01 Generic Robotic Workstation Operator's Guide* provides operating instructions for module assembly.

1.1 USING THIS DOCUMENT

This document is divided into five main headings. Chapter 1 provides a brief introduction to the document. It explains how to use the document, the conventions, and the menu/action sequences.

Chapter 2 is an overview of MAM. It explains how to use the windows and the main menu options.

Chapter 3 is a sample data base set-up procedure. By following the sample setup, the user should be able to perform a similar set-up alone.

NOTE

It is necessary to read Chapter 3 to set up the robot.

Chapter 4 is the utilities reference section. It provides detailed information about the utilities. If the user has additional questions after reading the set-up example, more detailed information will be found here.

Chapter 5 is the data base reference section. It provides detailed information about the data bases. If the user has additional questions after reading the set-up example, more detailed information will be found here.

The following information can be found in the back matter of this document.

- Appendix A contains all data base menus.
- Appendix B provides a list of program variables.

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- Appendix C shows a picture of the generic robotic workstation.
- The glossary provides definitions of terms used.

1.2 DOCUMENTATION CONVENTIONS

The text of this document uses the following conventions.

Convention	Meaning
Select "menu item"	Use the up arrow and down arrow keys to move the highlight within the menu; press RETURN to select the appropriate menu item.
Enter "response"	Type your response on the terminal keyboard at the "." or "= =>" prompt, then press RETURN. Do not include quotation marks.
Press KEYNAME	Press a key on the terminal keyboard or a button on the pendant.

1.3 MENU/ACTION SEQUENCE CONVENTIONS

MAM controls all the robot motion during the assembly. In addition to entering the necessary information on the keyboard, action by the user, such as physically moving the robot arm, is also required.

Menu/action sequences are provided in this document to guide the user through the software. Each menu/action sequence is divided into two portions. The top portion shows the procedure for adding new data base entities. The bottom portion shows how to modify previously defined data base entities. Menu/action sequences use the following conventions

Menu/Action Sequence Convention	Meaning
menu item	The first entry in a menu/action sequence is always a menu item. Use the up and down arrow keys on the keyboard to move within a menu. Press RETURN to select a highlighted item.
dash (–)	Select the menu item or entity immediately following the dash (–). If the items are listed vertically, select one or more items as needed.
arrow (= =>)	Enter a response on the keyboard. The type of response required is shown in square brackets following the "= =>". Do not include brackets.
asterisk (*)	Perform the action immediately following the asterisk. An example of an action is teaching a placement location.
Ellipses (...)	Ellipses (...) indicate that entries or actions are not included because they have been defined in previous headings.

Menu/Action Sequence Convention	Meaning
[square brackets]	Enter or select from the menu either a numeric or alphanumeric entity identifier such as the name of a feeder. Alphanumeric entities may contain up to 80 characters; however, it is recommended that only 10 to 12 characters be used to maintain readability of the screen I/O. Do not include brackets.

Following is an example of a menu/action sequence found in this document.

```
set-up - tool - add ==> [tool identifier] ... * teach tool z-reference

set-up - tool - modify - [tool identifier] - tool z-ref * teach tool
z-reference
```

The top portion of this sequence provides instructions for adding new tool information to the data base. The sequence instructs the user to do the following.

1. Select "set-up" from the main menu.
2. Select "tool" from the set-up menu.
3. Select "add."
4. Enter a 10- to 12-character alphanumeric tool name from the keyboard.
5. Intermediate steps that are omitted are indicated by the ellipses (...).
6. Teach the tool z-reference.

The bottom portion of this sequence provides instructions for modifying existing tool information in the data base. The sequence instructs the user to do the following.

1. Select "set-up" from the main menu.
2. Select "tool" from the set-up menu.
3. Select "modify."
4. Select a previously defined tool name from the menu.
5. Select "tool z-ref" from the menu.
6. Teach the new tool z-reference.

NOTE

MAM automatically advances through the appropriate menus. The user must only make the indicated selection or entry as each new menu appears.

CHAPTER 2

GENERAL INFORMATION ABOUT MAM

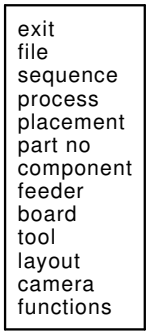
MAM is designed to reduce the set-up time of the robot using a simple data base structure. These data bases are then used to control the workstation during module assembly; see Figure 2–2. Currently, MAM is used for pick-and-place of surface mount components; however, with only minor modifications, the software can be adapted for other pick-and-place processes.

The MAM software contains two major components: utilities and data bases.

Utilities are software tools written to perform tasks repeated many times during the set-up of the robot workstation. For example, location teaching is the most frequently used utility; it requires the user to physically move the robot arm to a desired location.

Data bases store all the necessary parameters used during assembly; they must be created in sequence to use the software for pick-and-place. These data bases are accessible after selecting "set-up" from the main menu.

Figure 2–1: Set-up Menu



In Figure 2–3 the upper portion depicts a complete pick-and-place cycle and the interaction between the robot motion and the data base. This portion is called the "process." The lower portion of this figure shows the hardware information required to complete the process. This hardware information points to the process step where the information is needed. Note the relationship and the hierarchy of the data base. For example, the part number data base includes the feeder information as well as the component geometry information. This arrangement allows the user to create a process by referencing part numbers rather than the feeders.

Figure 2–2: Basic Information Managed by the MAM Data Base

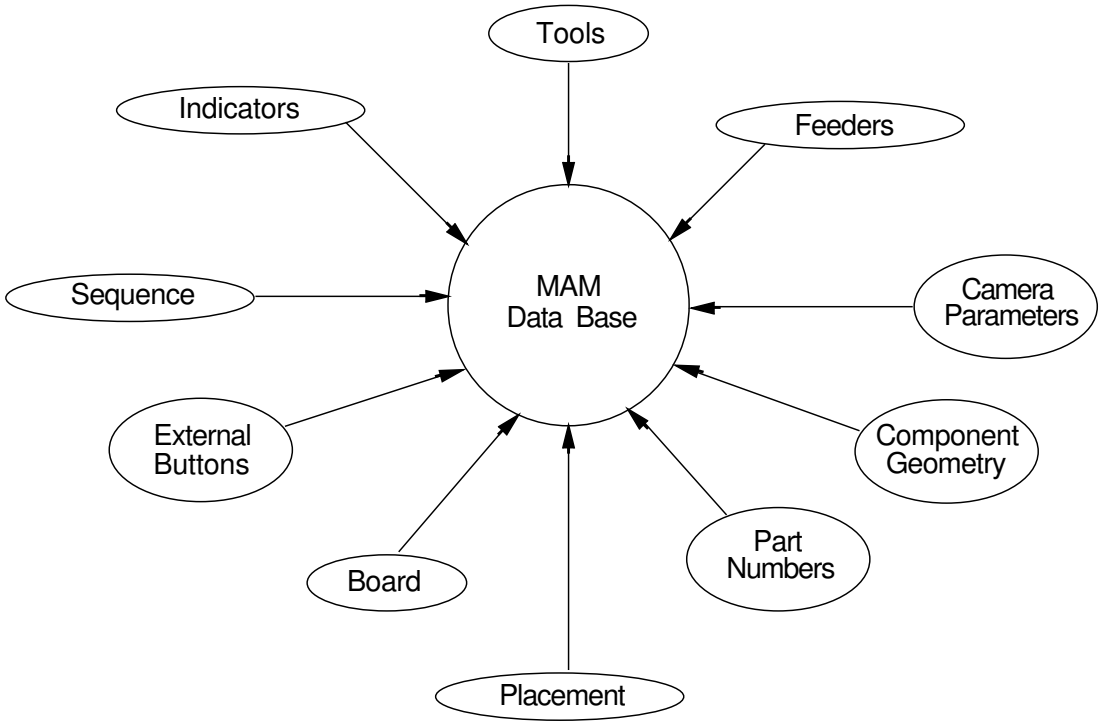
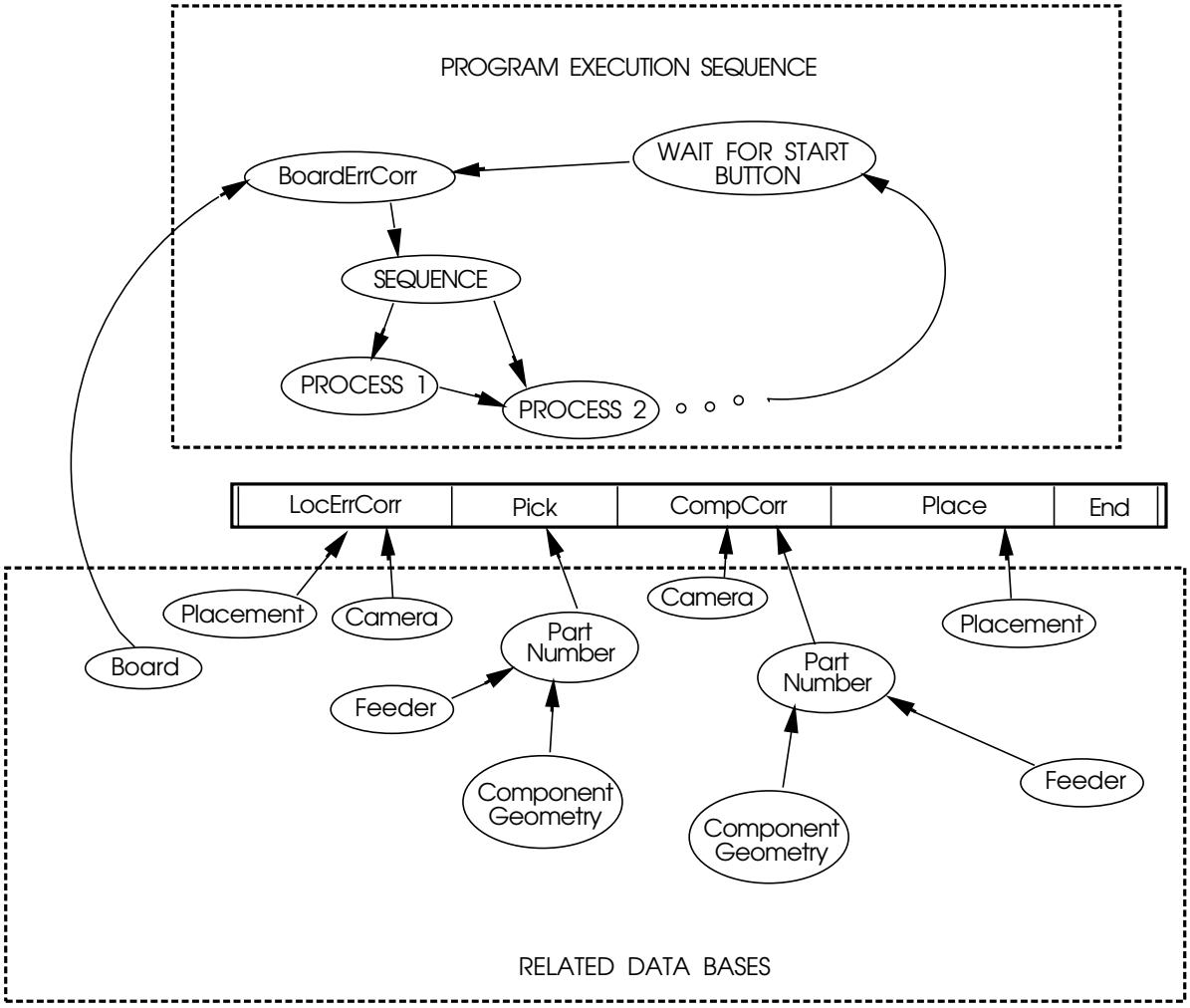
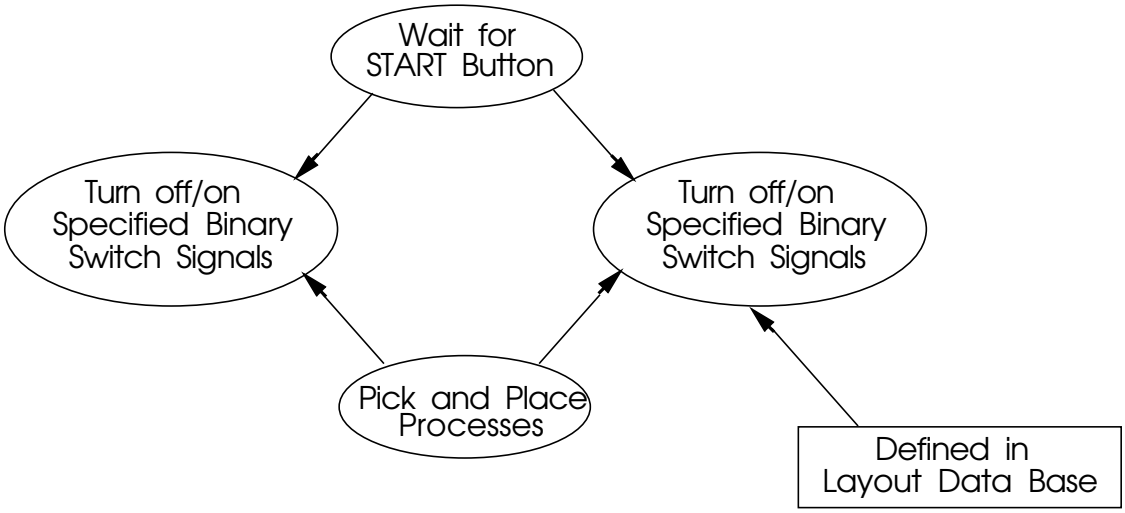


Figure 2–3: MAM Pick-and-Place Cycle and Associated Data Base Reference



As the START button is pressed, the sequence data base selects the processes to be executed. The necessary information in the data base will be managed by the process shown in the lower portion of Figure 2–3.

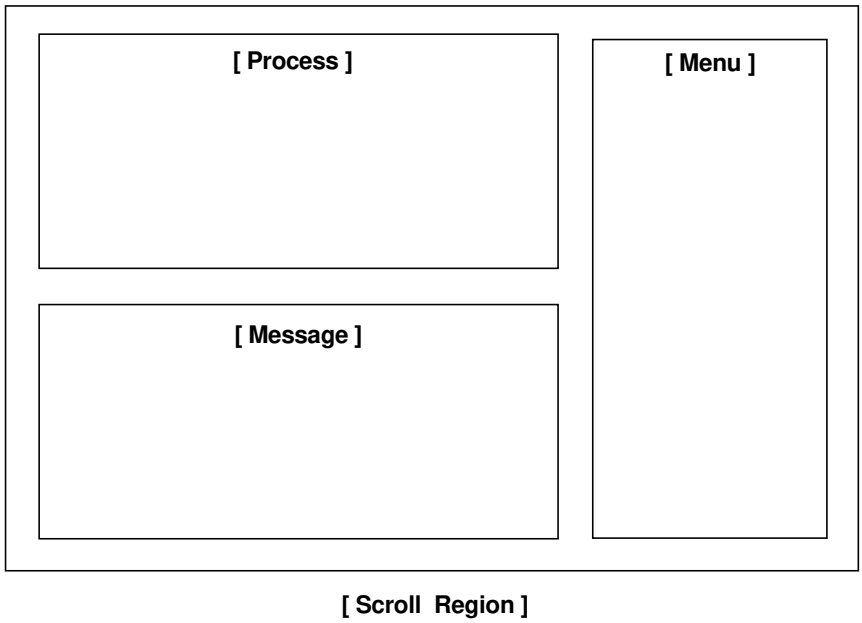
Figure 2–4: MAM Layout Data Base



2.1 SCREEN MANAGEMENT

MAM is partitioned into three windows: a process window, a message window, and a menu window. Figure 2–5 shows the MAM window layout.

Figure 2–5: MAM Window Layout



2.1.1 Process Window

The window on the top left of the monitor is the process window. This window displays the status of the data the user is creating.

2.1.2 Message Window

The window on the bottom left of the monitor is the message window. This window displays instructions or defines actions to be taken to complete the current data entry process.

2.1.3 Menu Window

The window on the right side of the monitor is the menu window. This window is automatically activated when menu input is required from the user. Menu items are listed vertically. Use the up arrow and down arrow keys on the keyboard to move the highlight within the menus. Press RETURN to select a highlighted entry.

The menu window contains up to 12 items per window. If more than 12 menu items are available, "scroll up" and "scroll dn" appear as the first and last menu items. Select "scroll up" to view the previous menu window or "scroll dn" to view the next window.

MAM menus have multiple layers. Each layer prompts the user for greater detail about the previous layer. The two menus used most frequently in MAM are the main menu and the set-up menu. The main menu includes options required for the daily operation of the robot; the set-up menu includes options required for system start-up and maintenance.

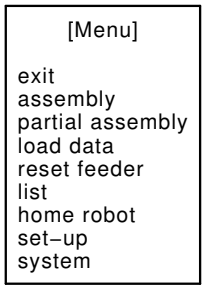
2.1.4 Scroll Region

Below the windows is a 6-line scroll region used for communication between the user and the robot controller. All data entered through the keyboard displays in the scroll region. The scroll region also displays instructions or defines actions to be taken to complete the current data entry process.

2.2 MAIN MENU

The main menu is the first menu to appear after executing MAM. See Figure 2–6. This menu contains items that direct the action of the robot. Select "set-up" to set up or modify data bases and other maintenance tasks. The operator selects "assembly" to start module assembly. The following subheads describe the main menu options.

Figure 2–6: Main Menu



2.2.1 Exit

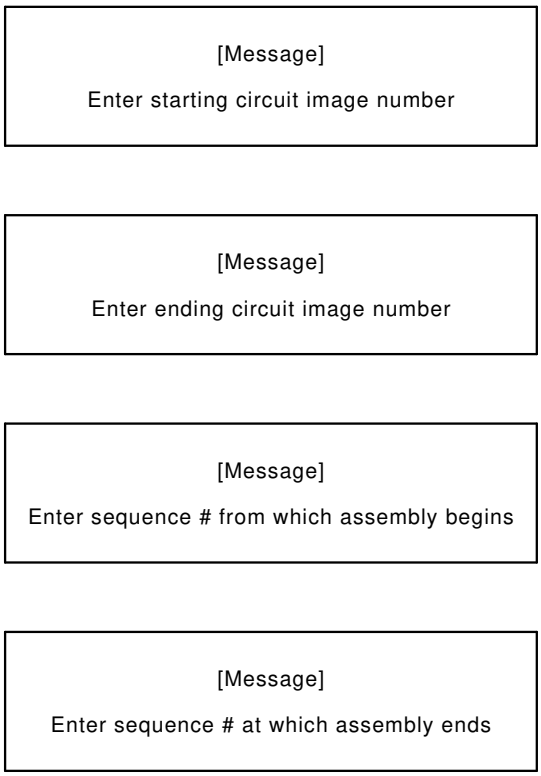
Select "exit" from the main menu to terminate MAM and return to the V+ operating environment. The V+ "." prompt appears.

2.2.2 Assembly

Select "assembly" from the main menu to start module assembly. If an external button is used to start the assembly process, MAM waits for the signal from the external button to begin the assembly process.

2.2.3 Partial Assembly

"Partial assembly" allows the user to begin or resume an assembly from within an assembly sequence. For example, the user can start an assembly from the third placement in the second circuit image to the fifth placement in the fourth image. The user needs to enter the beginning circuit image number and the ending circuit image number as well as the beginning sequence number in the starting circuit and the last sequence number in the ending circuit image. The following prompts appear:



2.2.4 Load Data

Data must be loaded from the disk file to start module assembly, otherwise, an error occurs and MAM terminates. If the user selects "load data" from the menu window, a list of available board file names appears in the menu. If, when storing data bases, all data is stored under one file name then all data can be found under the board extension file. If the data bases are stored separately, the user must select "file" from the set-up menu and load each data base individually. Use the arrow keys and press RETURN to select the file. An error message appears in the message window for a short period of time if an I/O error occurs.

2.2.5 Reset Feeder

Use the "reset feeder" option to reset the next pick cycle to the "first" feeder pick location. A matrix tray feeder can be reset so that the location for the next pick will be the "first" location. After selecting "reset feeder" from the main menu, a list of available feeders is displayed. Use the arrow keys to select the feeder(s) to be reset.

2.2.6 List

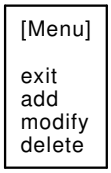
Select "list" to display the component part number(s) and the feeder(s) in which each part can be found.

2.2.7 Set-up

Use "set-up" to set up the data bases required for module assembly. For a detailed description of each data base see Chapter 5. "Set-up" also provides maintenance utilities that are used to add, delete, modify, list, or zero data base entities. See Section 4.2 for further information on maintenance utilities.

2.2.8 System

The system manager uses the "system" option to maintain the security data base. User access to the system can be added, modified, or deleted. When the user selects "system" from the main menu, the following menu appears:



I **Add user to system —** Use the following menu sequence to add a user to the system:

```
system - add ==> [username] ==> [password] ==> [access code]
```

After selecting "add," MAM prompts for the username, password, and access code. Both the username and password may contain up to 80 alphanumeric characters. The access code is a numeric value from 1 to 3 (inclusive).

II **Modify user profile —** Select "modify" from the system menu to change a user's password and access code.

```
system - modify - password - [username] ==> [new password]

system - modify - access code - [username] ==> [new access code]
```

a. Password — After selecting "password" from the "system modify" menu, a list of usernames appears in the menu. Select the appropriate username for the password to be changed and enter the new password.

b. Access Code — Select "access code" from the menu to modify an existing access code. The three levels of access codes are:

   1. System manager — can access all items in the main menu.
   2. Maintenance — can access all items in the main menu except "system."
   3. Operator — can access all items in the main menu except "system" and "set-up."

   A list of usernames appears in the menu. Select the appropriate username for the access code to be changed and enter the new access code.

III **Delete user —** Use the following menu sequence to delete a user from the system:

```
system – delete – [username]
```

When "delete" is selected from the system menu, all the usernames in the data base appear in the menu. Select the username to be deleted from the menu and press RETURN to delete the user.

2.2.9 Home Robot

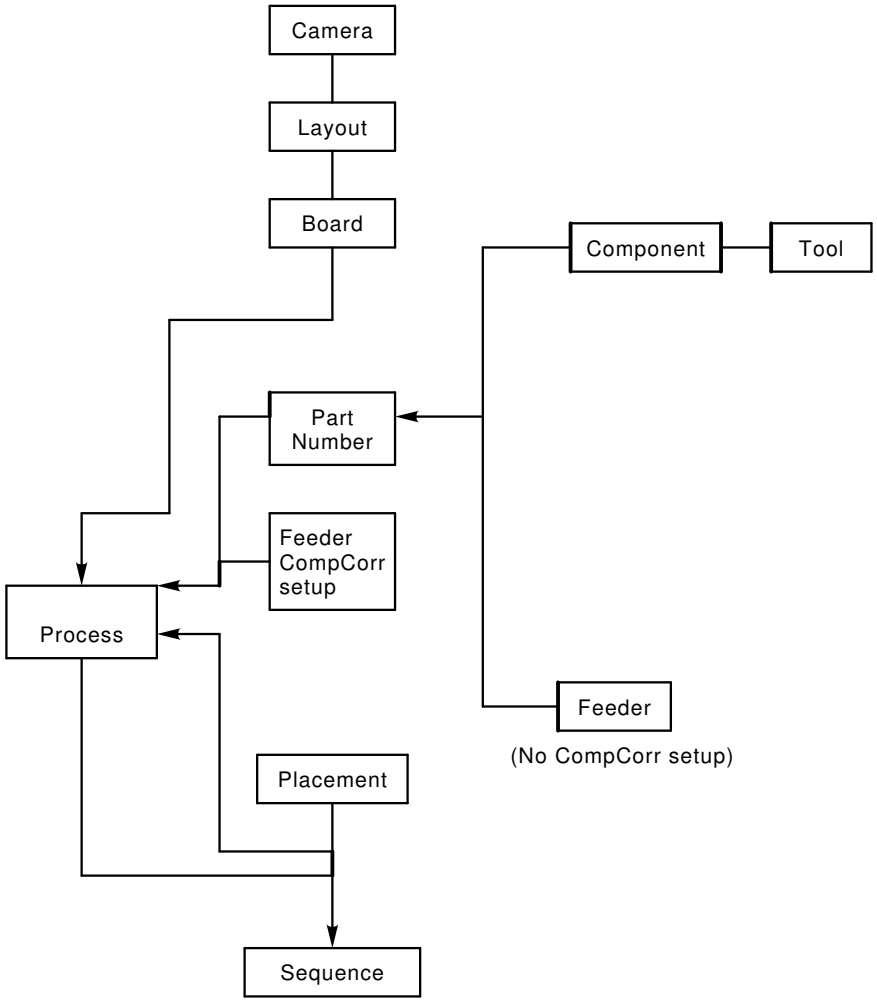
Selecting this option will raise the robot arm to the same Z-height as the "clear" location. See Section 5.2.1. The robot will then move to the final clear location. Even though the robot arm should clear all obstacles within the work area, the user should execute this option with care.

2.3 DATA BASE HIERARCHY

Since MAM manages the assembly process flow, the software is sensitive to the order in which data is input. For example, placement data cannot be input before the feeder data. If board error correction is required, board data cannot be input before the camera data. Figure 2–7 shows the data base hierarchy. Data bases at higher levels in this figure must be input before the data bases at the lower levels. Data bases at the same level can be input in any order.

Any change to a data base at a lower level does not affect those at a higher level. However, any change to a data base at a higher level may affect those at lower levels. For example, modifications to the sequence data base do not affect the process data base; however, any modification to the pickup location in the feeder data base will affect the placement location in the placement data base. To simplify the setup of the robot workstation, the process data base manages most of the other data bases. The user can select the process data base; other data bases, such as "placement" and "component," will be brought into the entire scheme to complete the setup.

Figure 2–7: Data Base Hierarchy



CHAPTER 3

SAMPLE DATA BASE SET-UP PROCEDURE

This section steps through the entire procedure to set-up a workstation. Two cameras, "camera 1" and "camera 2", are used. The name of the feeder is "array". At the end of the sample session the user will be able to build the board named "PWB." The procedure includes board error correction, local error correction, pick-up component "164p 25mnh" with 164 pins, 25-mil pitch and no heat sink. The part number of the component is "20-12345", the reference designation of the placement is "E10."

"Enter" means keyboard input is required; "select" means a menu item must be selected.

The vision must be enabled by entering "lo auto" followed by "com auto" and MAM must be executed to start the vision process. This is usually done during auto boot.

The entries in brackets are for example only.

a. Set up the **CAMERA** data base:

   1. Power up the workstation and log onto the system manager account as described in EL-MF519-01.
   2. Select "set-up".
   3. Select "camera".
   4. Enter camera name. [camera1]
   5. Select serial communication port. [user1]
   6. Select camera configuration "arm mount".
   7. Enter physical camera number. [1]
   8. Enter number of calibration performed on the camera. [1]
   9. Teach the "clear" location.
   10. Teach four arbitrary locations as prompted by the program.
   11. Put the black calibration disk (or a black dot against a white background) in place. Move the robot arm until the calibration disk appears at the approximate center of the camera's field of view (FOV).

NOTE

The diameter of the disk showing on the monitor should be approximately 25% of the monitor display dimension in order to obtain accurate calibration.

   12. Select the image condition of dark against bright background or bright against dark background.
   13. Adjust the image quality as needed.

14. The robot arm begins the calibration routine. Observe the vision monitor carefully; notice that the robot arm pauses at certain locations. Ensure that the white circle stays within the camera's FOV during this series of movements.
15. Move arm to lefty configuration until camera sees the circular dot.
16. Select "yes" if the image stayed within the camera's FOV at the pause location. Otherwise select "no" and repeat from step 14.

NOTE

Robot calibration requires approximately three minutes.

17. Select "yes" to fine tune the camera.
18. Enter arm scanner input signal. [1006]
19. Put the plated-through hole calibration plate in place. Move the robot arm to a location where the scanner's laser beam is at the approximate center of the hole; a red, plastic filter on top of a piece of white paper will help to locate the laser beam. Press REC/DONE on the pendant. The calibration gripper must be in place. This routine is easier to perform with the overhead lights turned off.
20. Repeat step 19 two additional times. (Rotate the fourth axis of the robot arm approximately 120°.) Ensure that the scanner's laser beam remains at the approximate center of the hole.

NOTE

If more than one calibration was indicated in Step 9, the program returns to Step 11 at this point.

21. Turn on the overhead lights. Move the robot arm until the hole appears at the approximate center of the camera's FOV and press REC/DONE.
22. Adjust the image quality as needed.
23. Clear the work envelope and press RETURN. The robot proceeds to scan the hole using the laser scanner.
24. Place any PWB inside the work envelope.
25. Move the robot arm until a fiducial appears at the center of the vision monitor for the image quality default setting. (If using V^+ version 8 or higher, adjust the threshold until the image appears brighter than normal.)
26. Move the robot arm within the work envelope to ensure that the image quality is acceptable throughout the work envelope. Press REC/DONE to terminate the image adjustment.
27. Select "yes" if the image default setting is satisfactory throughout the entire work envelope. Otherwise, select "no" and repeat from step 20. These steps complete the arm-mount camera calibration.

NOTE

The following procedures are used to add an UP-LOOKING camera.

28. Select "add".
29. Select serial communication port. [user1]
30. Select camera configuration "up-looking".
31. Enter physical camera number. [2]
32. Teach the z-height with the calibration probe attached.
33. Move the robot arm until the calibration disk appears at the approximate center of the camera's FOV. The calibration gripper must be in place.
34. Adjust the image quality as needed. It helps to shut the lights off here.
35. The robot arm begins the calibration routine. This routine is easier to perform with the overhead lights turned off. Observe the vision monitor carefully; notice that the robot arm pauses at certain locations. Ensure that the white circle stays within the camera's FOV at the pause location.
36. Select "yes" if the image stayed within the camera's FOV at the pause location. The robot proceeds with the calibration. Otherwise, select "no".
37. Select "yes" if the starting location needs to be adjusted. Otherwise, select "no" and the software will return the user to step 29.

NOTE

To start robot calibration requires approximately three minutes.

38. Select "exit".

b. Set up the **LAYOUT** data base:

1. Select "layout".
2. Select "new" from the menu.
3. Teach the CLEAR location.
4. Teach the REJECT location.
5. Teach the z-reference of the probe.
6. Teach the z-height of the table.
7. Enter the signal number for the part present sensor. [1007]
8. Enter the robot output signal to be turned "on" during pick and place. ("0" to terminate.) [28]
9. Enter the signal number for the START button. [1004]
10. Enter the signal number for the HOME button. [1003]
11. Enter the signal number for the TERM button. [1002]
12. Enter the signal number for the RESET button. [1001]
13. Enter the signal number for the emergency bypass switch. [1009]
14. Enter the signal number for the emergency light. [30]
15. Enter the signal number for the function light. [29]

16. Enter the signal number to be turned off during emergency stop.
17. Select "no" to bypass clincher setup.
18. Re-enter layout data if necessary.
19. Select "exit".

NOTE

If the board data is not downloaded at this point, the placement data cannot be downloaded.

c. Set up the **BOARD** data base:

1. Select "board".
2. Select "add".
3. Enter board name. [PWB]
4. Select "yes" to teach board reference.
5. Select camera for board error correction.
6. Select "yes" to set up for board error correction.
7. Select camera for board reference teaching.
8. Move arm until camera sees the reference fiducial. In general, the board fiducials are used; two fiducials are required.
9. Teach the fiducial location.
10. Adjust the image.
11. Adjust the vision window.
12. Repeat steps 7 to 11 for the second reference fiducial.
13. Enter board reference fiducial coordinate 'x' with respect to H-master coordinate.
14. Enter board reference fiducial coordinate 'y' with respect to H-master coordinate.
15. Enter the first board fiducial coordinate 'x' with respect to H-master coordinate.
16. Enter the first board fiducial coordinate 'y' with respect to H-master coordinate.
17. Enter vision window size to capture the image. [0.07]
18. Enter the second board fiducial coordinate 'x' with respect to H-master coordinate.
19. Enter the second board fiducial coordinate 'y' with respect to H-master coordinate.
20. Enter vision window size to capture the image. [0.07]
21. Enter the third board fiducial coordinate 'x' with respect to H-master coordinate.
22. Enter the third board fiducial coordinate 'y' with respect to H-master coordinate.
23. Enter vision window size to capture the image. [0.07]
24. Enter the board thickness.
25. Select "exit".

d. Set up the **PROCESS** data base:

1. Select "process".
2. Select "add" to add new process.

3. Enter process name. [pick&place]
4. Select "LocErrCorr" for local error correction.
5. Select "pick".
6. Select "input" to add part number.
7. Enter part number. [12345]
8. Select "create" to create part number. At this point MAM begins to create the part number data base. When completed, MAM returns to the process data base and continues.

e. Set up part **NUMBER** data base.

1. Select "input" to add new component. At this point MAM begins to create the component data base. When completed, MAM returns to the part number data base and continues.
2. Enter component name. [164p25mnh]
3. Select "create".

f. Set up the **COMPONENT** data base:

1. Enter the component name.
2. Enter the number of leads per side. [41]
3. Enter the lead spacing. [25]
4. Enter the component height. [3.5]
5. Enter the grip height offset. [0]
6. Enter the insertion length. [0]
7. Enter the component carrying speed. [1000]
8. Select the component style (sm = surface mount, th = through-hole).
9. Select "input" to add new tool.
10. Enter tool name. [vacuum]
11. Select "create". At this point MAM begins to create the tool data base. When completed, MAM returns to the component data base and continues.

g. Set up the **TOOL** data base:

1. Enter the grip signal number. [18]
2. Enter the release signal number. [-18]
3. Enter the limit open option signal number. [0]
4. Enter the hand time. [0.3]
5. Enter the tool ID signal 1.
6. Enter the tool ID signal 2.
7. Enter the tool ID signal 3.
8. Enter the tool main cut-off signal. [0]
9. Enter the tool rack signal. [0]

10. Enter the z-displacement sensor signal. [1006]
11. Teach the tool z-reference.
12. Enter the tool rack approach height (minimum 45 mm for the applied robotic x-change system).
13. Enter the number of tool rack clear path locations.
14. Teach the clear path location.
15. Teach the tool rack location.
16. Move the arm to a location clear of all obstacles.
17. Re-enter tool data if necessary.
18. System now returns to component data base.
19. Re-enter component data if necessary.
20. System now returns to part number data base.
21. Select "input" to create new feeder.
22. Enter feeder name. [array]
23. Select "create". At this point MAM begins to create the feeder data base. When completed, MAM returns to the part number data base and continues.

h. Set up the **FEEDER** data base:

1. Enter the feeder name.
2. Enter the approach height.
3. Enter the feeder request signal.
4. Enter the feeder ready signal.
5. Enter the number of components in the x-direction.
6. Enter the number of components in the y-direction.
7. Enter the internal/external index. (For example, use the internal index for matrix tray and the external index for the intelligent feeder.)
8. Enter the x-offset. (array feeder only)
9. Enter the y-offset. (array feeder only)
10. Select the camera.
11. Move the robot arm until the frame origin is at the approximate center of the camera FOV. This is for the array feeder only. (Use the square calibration plate for 1×5 matrix feeders.)
12. Move the robot arm until frame positive-x is at the approximate center of the camera FOV. (array feeder only)
13. Move the robot arm until frame positive-y is at the approximate center of the camera FOV. (array feeder only)
14. Enter the number of clear locations. [n]
15. Teach clear path point. (1...n)
16. Teach the probe z-reference.

17. Teach the z-height of the feeder seating plane.
18. Teach the seating plane x-y location.
19. Teach the component x-y location.
20. Clear the work envelope and press RETURN twice.
21. Select "yes" to set up for component correction only if part numbers were previously entered.
22. Enter the camera approach height.
23. Select "camera2" for component correction.
24. Move the component to the camera's FOV.
25. Adjust the image quality as needed.
26. Re-enter feeder data if necessary.
27. System returns to part number data base.
28. Re-enter part number data if necessary.
29. System returns to process data base.
30. Select "CompCorr" for component correction.
31. Select "place".
32. Select "input" to add new placement.
33. Select "create". At this point MAM begins to create the placement data base. When completed, MAM returns to the process data base and continues.

i. Set up the **PLACEMENT** data base:

1. Enter placement identification. [E10]
2. Enter approach height.
3. Enter number of clear path point "0".
4. Select "download" as placement method.
5. Enter H-master coordinate 'x' of component centroid.
6. Enter H-master coordinate 'y' of component centroid.
7. Enter H-master angle of component.
8. Select "yes" for local error correction.
9. Select "camera1".
10. Select "both" to teach the fiducial location as well as to adjust the image quality.
11. Select "all" to teach both the first and second fiducial.
12. Enter H-master coordinate 'x' of first fiducial.
13. Enter H-master coordinate 'y' of first fiducial.
14. Enter size of vision window to capture the fiducial. [0.07]
15. Enter H-master coordinate 'x' of second fiducial.
16. Enter H-master coordinate 'y' of second fiducial.
17. Enter size of vision window to capture the fiducial. [0.07]

18. Re-enter placement data if necessary.
19. System returns to process data base.
20. Select "end of process" to terminate process data entry.
21. Select "exit".

j. Set up the **SEQUENCE** data base:

1. Select "sequence".
2. Select the process name "pick&place".

CHAPTER 4

UTILITIES

4.1 DATA BASE UTILITIES

Data base utilities are standard protocols to facilitate adding to or modifying a data base. The location teaching utility provides a standard protocol for teaching robot arm locations. The vision window utility provides a protocol for adjusting the vision window.

Figure 4–1 shows the maintenance menu. Items listed in the maintenance menu such as feeder, placement, and sequence information are managed by a standard maintenance utility. This utility enables the user to add, copy, delete, modify, zero, or list data that is stored in memory. Select "exit" to return to a higher level menu.

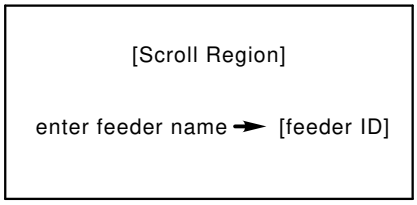
Figure 4–1: Maintenance Menu

4.1.1 Add

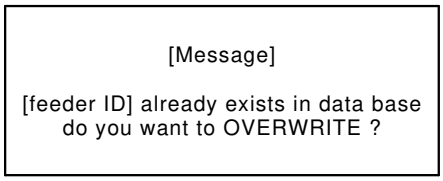
Select "add" from the maintenance menu to create a new data base entity. When adding new data to the data base, MAM automatically prompts for required information in sequential order.

For example, the following menu sequence is used to add feeder information to the data base. The new feeder, "feeder ID," is entered on the keyboard and appears in the scroll region as shown.

```
set-up - feeder - add ==> [feeder ID]
```



When you enter the feeder name, MAM checks the data base for an existing entity (feeder in this case) with the same name or identification number. If it finds a match the following message appears:



Select "yes" from the menu to overwrite the existing entity information or "no" to abort the operation.

If the name or identification number of the entity does not exist in the data base or the overwrite option is selected, MAM prompts for additional information related to the selected entity.

NOTE

Store new data to disk files as frequently as possible. Data that is not stored to disk files will automatically be deleted if the system is powered down. Refer to Section 4.2.2 for further information.

4.1.2 Copy

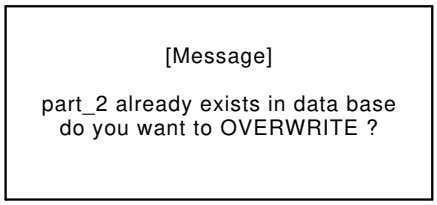
New data base entities can be created by copying data from an existing data base entity. For example, use the following menu sequence to copy the existing component entity "co_old" to the new component entity "co_new":

```
set-up - component - copy - [co_old] - input ==> [co_new]
```

You can overwrite existing entities by copying data from another existing entity. For example, if part numbers "part_1" and "part_2" both exist in the data base, the following menu sequence copies information from "part_1" to "part_2".

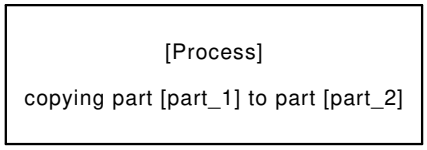
```
set-up - part - copy - [part_1] - [part_2] - yes
```

The following message appears to confirm that "part_2" already exists in the data base:

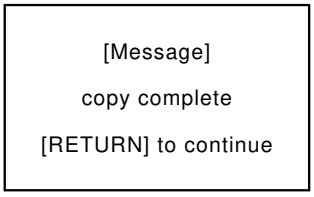


Select "yes" from the menu to overwrite the existing data or "no" to abort the operation.

When selecting menu items, the process window displays interactive process messages. The following message is the final message that appears in the process window after "part_1" and "part_2" are chosen from the menu:



When the copy process is complete, the following message appears:



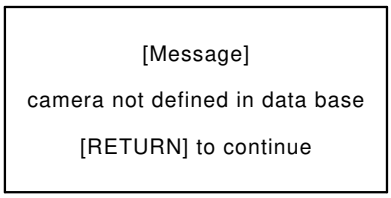
Press RETURN to continue.

4.1.3 Delete

Select "delete" from the menu to delete files from the data base. For example, you can delete camera "1" from the data base by selecting the following menu options:

```
set-up - scroll dn - camera - delete - 1
```

If camera "1" does not exist in the data base, the delete operation is aborted and the following message appears:



Press RETURN to terminate the deletion process.

4.1.4 Zero

The "zero" option is used to reset the data base index to "0". This is equivalent to erasing the selected information from the data base. For example, use the following menu sequence to erase all placement information from the data base:

```
set-up - placement - zero
```

This option is especially useful when teaching a new module, providing that the workstation layout, feeder, and other information are the same. For example, you can teach a new module by following these steps:

1. Load data from a previously taught module.
2. "Zero" the placement and other data bases (process and sequence data bases in most cases) if necessary.
3. Teach placement data using the placement data base utility or another data base (process data base in most cases) if necessary.

4.1.5 Modify

Select "modify" from the menu to change existing data base entities. Select the specific entity name and parameter to be changed from the menu. For example, you can modify the component height of the component "co_name" by selecting the following menu options:

```
set-up - component - modify - [co_name] - height ==> [component
height]
```

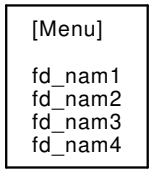
The software prompts for actions or input required to change the height of the component in the data base.

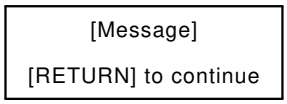
4.1.6 List

Select "list" from the menu to display specific entity names. For example, to list feeder names on the monitor use the following menu sequence:

```
set-up - feeder - list
```

The names of the feeders appear in the menu window as follows:





Press RETURN to continue to the next process.

4.2 FILE MANAGEMENT UTILITY

```
set-up - file - exit
               - load data
               - store data
```

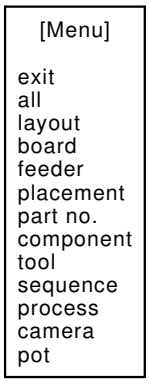
Select "store data" for the menu to store data bases from RAM to a disk. Select "load data" from the menu to load data bases from a disk to RAM. Each data base is stored under the same file name with different file extensions. Figure 4–2 shows the data bases and their file extensions.

Figure 4–2: Data Base File Extensions

Data Base	File Extension
layout	.lo
board	.bo
feeder	.fd
placement	.pl
part no.	.pa
component	.co
tool	.to
sequence	.se
process	.pr
camera	.ca

4.2.1 Load Data

When you select "load data" from the menu, the following menu appears in the menu window:



Select "all" to retrieve all information for a particular file name. Otherwise, select only the data base containing the necessary data. The current data will be overwritten as the data file(s) is loaded. For example, select "feeder" from the menu to load only the feeder data base. Any feeder information currently stored is overwritten by the new data. After selecting the data base to be loaded, all data files with the corresponding file extension are shown in the menu. Select the appropriate file name by using the arrow keys. If you select "all", the file name with ".bo" is listed in the menu. If an error occurs during the loading process, an error message appears in the message window.

4.2.2 Store Data

When you select "store data", all the data bases are displayed in the menu window. Select "all" to write all information to the disk. Otherwise, select only the file extension containing the necessary data base. The current data will be written to the disk file with the appropriate file extension. For example, select "feeder" from the menu to write only the feeder data base to the disk. After selecting the data base to be written to disk, MAM prompts the user to input the file name. Enter the file name after the "==>" prompt in the scroll region.

NOTE

The file name should not exceed seven characters.

In a production environment, after all the data is taught or downloaded, select "all" to store the data under one file name. In this way, an operator need only load one data file containing all the stored data.

4.3 LOCATION TEACHING UTILITY

All locations are taught using the utility defined in this heading. Refer to this heading when location teaching is required.

The following are examples of some locations that must be taught and stored in the data base for use in module assembly:

- Part pick-up
- Component correction camera
- Placement
- Fiducial

The following prompt appears in the message window when location teaching is required:

```
[Message]

Use pendant to teach location
   <COMP/PWR> to continue
<REC/DONE> to record location
```

When this message appears, the robot arm is "detached" from the controller and the manual mode on the pendant can be used. Refer to the *Adept Manipulator System Basic Operation Manual* for further information on "detach" and for instructions on controlling the robot through the manual pendant.

Use the following procedure when teaching robot manipulator locations:

1. Press MAN on the pendant to put the robot into manual mode.
2. Move the robot arm to the desired location using "world," "tool," "joint," or "free" mode.
3. Press COMP/PWR to lock the robot arm into place and to return control to MAM.
4. Check the location of the robot arm again to ensure that the location is correct. If the robot's location has shifted, press MAN to return to manual mode and re-teach the location as described in steps 1 and 2.
5. Press REC/DONE to record the location information. A beep indicates that the locational information was recorded. The following message appears on the monitor:

```
[Message]

clear work envelope

[RETURN] to continue
```

6. Press RETURN to complete the location teaching process.

NOTE

The REC/DONE button on the pendant may have to be pressed several times in order to clear the pendant buffer. Make sure that you hear a beep before moving to the next step. If you press REC/DONE before COMP/PWR, the terminal will not respond to the keyboard. If this occurs, press COMP/PWR to continue programming.

When the location teaching utility is activated, the LCD on the pendant should show "release", "grip", and "previous" directly above the first three soft buttons from the left. (See the Adept basic manual). "Release" and "grip" only appear if the tool was defined in the tool data base, otherwise the words will not appear on the pendant. Press the soft button directly below "release" to "open" the end-effector. Press the soft button directly below "grip" to "close" the end-effector.

"Previous" points to the location taught previously. When you press the soft button directly below "previous", the robot arm retracts to a "clear" height and moves to the location taught previously. In the MAM software, the "previous" function has been carefully defined in the most logical sense. However, the "previous" location does not necessarily equal the location the user desires.

When you press the soft button directly below "previous", the data terminal beeps and the following message appears in the message window:

```
[Message]

Make sure pendant is in <COMP/PWR>
mode.
Clear Work envelope.
        <RETURN> to continue.
```

Make sure the pendant is in <COMP/PWR> mode and clear the work envelope. Press RETURN and the robot retracts to the "clear" height and moves slowly to the previously defined location. Watch carefully to make sure there is no obstacle within the path of the robot.

4.4 VISION WINDOW SET-UP UTILITY

The vision window defines the boundary for vision image processing. It accelerates the vision processing speed and reduces the risk of picking up erroneous information from features with similar geometry.

For example, if there are many circular solder pads on the same PWB, a vision window that encloses only the targeted solder pad is required. In this case, only the targeted circular solder pad information is processed and the other circular solder pads are ignored by the vision system. MAM provides a utility for defining the vision window using the arm-mount camera.

Follow these steps to complete the vision window setup:

1. Use the pendant to move the robot arm until the targeted object appears at the approximate center of the camera's field of vision (FOV). The following message appears in the scroll region:

[Scroll Region]

move arm until {object} is at approx center of camera's FOV

2. Press COMP/PWR then REC/DONE on the pendant to record the location.
3. Adjust the image quality. The following message appears in the message window:

[Message]

Do you need to adjust image?

4. Select "yes" from the menu to adjust the image quality. This invokes the image quality utility. See Section 4.5 for instructions. Select "no" if the current image quality is acceptable.
5. Define the size of the vision window so that the targeted object is enclosed in the window. The outline of the vision window appears on the vision monitor and the following message appears in the message window:

[Message]

pendant activated

'up' 'down' 'left' 'right' arrows to move window
speed pot '+' '–' to change window size

Use the "up," "down," "left," and "right" arrow keys on the pendant to move the window on the monitor. These buttons can be pressed simultaneously. Press "speed pot +" to enlarge the window size, and "speed pot -" to reduce the window size.

6. Press REC/DONE to record the location and terminate the vision window set-up.

NOTE

The vision window must be large enough to allow misregistration of the PWB but small enough to exclude other features of the PWB.

4.5 IMAGE QUALITY UTILITY

Use the image quality utility to adjust the gain, offset, and threshold of the vision system.

- Gain — Adjusts the contrast of the image to make the bright spot brighter.
- Offset — Adjusts the sensitivity of the vision system to the intensity of the incoming light.
- Threshold — Adjusts the binary image quality.

These adjustments are integrated into MAM and can be controlled through the robot pendant.

The image on the vision monitor is a live gray scale image or live binary image. The settings of the gain, offset, and threshold appear in the top left corner of the monitor.

The "speed pot +" and "speed pot -" buttons on the pendant are used to adjust the offset and threshold of the vision system. Use the leftmost soft button to toggle between offset and threshold adjustment. The LCD on the pendant (directly above the soft button) shows the mode of adjustment to which "speed pot" is set. Refer to the *Adept Manipulator System Basic Operation Manual* for details on pendant layout.

When in the offset mode, pressing "speed pot +" increases the offset of the system and makes the live image appear darker. Pressing "speed pot -" decreases the offset of the system and makes the live image appear brighter.

When in the threshold mode, pressing "speed pot +" increases the threshold of the system and makes the binary image appear darker (more black background). Pressing "speed pot -" decreases the offset of the system and makes the binary image appear brighter (more white background).

The gain can be adjusted by pressing the "+/YES" and the "-/NO" buttons on the pendant. Press "+/YES" to increase the gain of the system. The bright object will appear brighter when the gain setting is increased. Press "-/NO" button to decrease the gain setting. The bright object appears less bright when the gain setting is decreased.

The image shown on the vision monitor can either be a live gray scale image or a live binary image. The image mode can be set by toggling the second left-most soft button on the pendant. The image mode setting is displayed on the LCD directly above the soft button. The user should determine whether the image will be processed as binary image or as gray scale image. If the process is binary, the image quality will be determined by the live binary image.

4.6 FUNCTIONS

The functions in MAM are written to facilitate data downloading; therefore, if a module is not set up using the data downloading feature, "functions" cannot be selected from the menu to perform any meaningful task.

4.6.1 Measure

```
set-up - functions  - measure
```

Measure uses the arm mount camera to locate the centroid of an object on the PWB with respect to the H-master coordinate. Use this function to obtain the following information:

1. The centroid of the first object seen by the arm mount camera with respect to the H-master coordinate.
2. The centroid of the second object seen by the arm mount camera with respect to the H-master coordinate.
3. The midpoint of the two objects with respect to the H-master coordinate.

This information is useful when the user needs to determine the centroid of the lead frame. For example, use the camera to see the two local fiducials of a particular component pad pattern. The program displays the coordinates and the midpoint of the two fiducials shown. The midpoint is usually the centroid of the component pattern on the PWB. When local fiducials are not available, use the pad at the two opposite corners; the midpoint should indicate the centroid of the component pattern.

When "measure" is selected, the following reminder displays in the message window:

```
Board fiducials must be downloaded to use the function
```

Select the appropriate camera to see the object; the vision monitor displays an image of the selected camera. Using the teach location utility, move the robot arm until the first object appears on the vision monitor and teach that location using the window utility. A picture is taken and the user is prompted to select the appropriate camera to see the second object. Follow the same procedure to teach the second object.

After the second picture is taken, the coordinates of the first object appear in the message window. Press RETURN to see the midpoint of the two objects. If more measurements are needed, select "yes" to continue; otherwise, select "no" to return to the set-up menu.

4.6.2 Shift Placement

```
set-up - functions - shift pl
```

The shift placement function shifts the placement location with respect to the H-master coordinate. When this option is selected, a list of placement names appears in the menu. Select the name of the placement to be shifted. Enter the values of the shift in the "x", "y", and "theta" dimensions.

CHAPTER 5

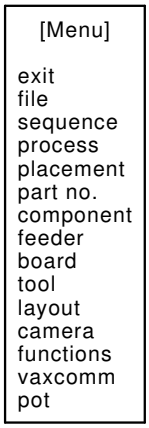
DATA BASE REFERENCE

MAM is designed to control the assembly processes and store the data bases that support these processes. Several types of data bases are required to support the pick-and-place process. The data bases within MAM are:

- Camera — Stores all information related to the calibration setup of the vision camera.
- Layout — Stores all information related to the signal and hardware setup of the workstation.
- Board — Stores information related to the board error and the geometry of the printed-wiring board.
- Process — Provides pointers for the software to retrieve data from other data bases to complete the pick-and-place process.
- Part Number — Assigns components to a specific feeder. A part number is then assigned to this component.
- Component — Stores all information related to component geometry.
- Tool — Stores all information related to the signal and hardware setup of the end-effector.
- Feeder — Stores all information related to the location, signal, and setup information for component correction.
- Placement — Stores information related to component placement locations.
- Sequence — Directs the order of execution of the pick-and-place process.

Select "set-up" from the main menu to display the data base menu, shown in Figure 5–1.

Figure 5–1: Data Base Menu



With the exception of the process data base and the sequence data base, each data base is a collection of robot I/O signal numbers, various calibration parameters, and robot arm locations. Each data base is defined in detail in this section.

5.1 CAMERA DATA BASE

The camera data base stores camera calibration parameters. Camera data can be added, deleted, or modified by selecting "camera" from the set-up menu. The camera configurations supported by MAM are:

- Table mount upward-looking camera
- Arm mount downward-looking camera

Section 5.1.1 through Section 5.1.3 provide instructions for adding to or modifying the camera data base.

5.1.1 Identification

```
set-up - camera - add ==> [camera ID]
```

The camera identification number is same as the virtual camera number of the vision system. For example, if virtual camera "2" on the vision system is used, the camera identification number on the robot workstation should also be "2". Refer to the *Stand-Alone Vision System User Guide* for further information.

5.1.2 Communication

```
 set-up - camera - add ==> [camera ID] - upward looking
                                       - arm mount
- user 1
- user 2
- user 3
- user 4
- user 5


 set-up - camera - modify - [camera ID] - communication
- user 1
- user 2
- user 3
- user 4
- user 5
```

The robot uses a serial communication port to send and extract command information with the vision system. There are five serial communication ports available on the Adept robot. See the *Adept Manipulator System Basic Operation Manual*. These serial ports are labeled user 1 through user 5. Depending on the physical wiring of the robot and the vision system, select the serial communication port that is connected to the vision system.

5.1.3 Configuration

```
set-up - camera - add ==> [camera ID] - upward looking
                                      - arm-mount


set-up - camera - modify - config - upward looking arm-mount
```

Specify either the arm-mount or the table-mount camera configuration.

The camera configuration affects the method to be used for camera calibration. If the configuration of a previously defined camera is changed, the calibration routine will automatically be invoked.

For example, a camera that was previously defined as a table-mount can be re-defined as an arm-mount camera. The arm-mount camera's calibration routine is automatically invoked and the user is prompted through the calibration procedure.

5.1.4 Physical Camera Number

```
set-up - camera - add ==> [camera ID] ==> [physical camera number]


set-up - camera - modify - [camera ID] ==>[physical camera number]
```

Each camera is assigned a physical camera number by the vision system based on the camera connection to the vision system.

5.1.5 Camera Calibration

Two camera calibrations exist. One is the arm-mount camera; the other is the table-mount camera.

5.1.5.1 Arm-Mount Camera Calibration

```
set-up - camera - add ==> [camera ID] - arm-mount ...

set-up - camera - modify - [camera ID] - calib ...
```

The arm-mount camera calibration procedure calculates the relative location of the camera with respect to the robot arm. A calibration disk, a sheet or 8 × 11.5-inch black construction paper, and a sheet of 0.25 × 0.25-inch white construction paper are required for the calibration. Refer to the *Stand-Alone Vision User Guide* for further information.

The robot must be powered up and calibrated before camera calibration. The vision must be enabled and V_MAM must be executed.

To prepare for the calibration (Option 1):

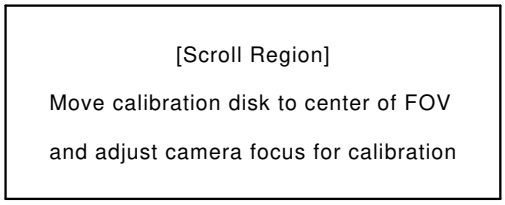
1. Position the black construction paper on the surface where the vision image is to be acquired.
2. Position the white construction paper at the approximate center of the black construction paper.
3. Position the calibration disk on top of the white construction paper so that the white construction paper is visible ONLY through the hole of the disk.

To prepare for the calibration (Option 2):

1. Center a black dot on a transparent plastic sheet; place the transparent sheet on a sheet of white paper.

The image of the specified camera will appear on the vision monitor. The user is requested to enter the number of times the calibration will be performed; at least one calibration must be performed. The parameters from the calibrations are averaged to obtain the final calibration data. Teach a clear location. However, if MAM is aborted the prompt to teach a clear location will not display again; MAM stores the original clear location. After entering the number of calibrations, move the robot arm to four arbitrary locations at least five inches apart. These locations are used to calculate the robot link dimension. After teaching these four locations, the link dimension appears in the menu window. The dimension of link one should be 425 ± 0.10 mm; link two should be 375 ± 0.10 mm. If the dimension shown in the menu window falls outside the stated range, abort the calibration in progress and begin a new calibration.

After choosing the above menu sequence, the following message appears on the monitor:

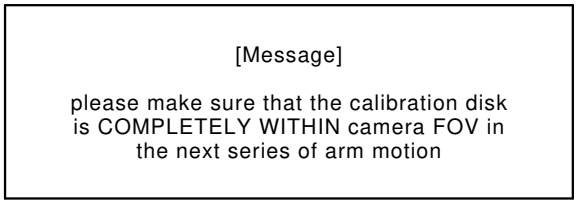


The following steps are required to complete arm-mount camera calibration:

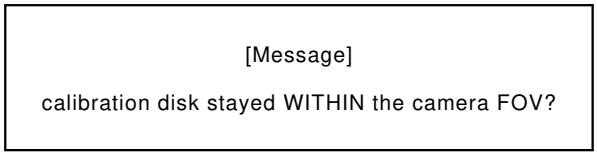
1. Move the robot using the pendant until the circular hole or black dot of the calibration disk is clearly shown at the approximate center of the camera's FOV. The diameter of the hole shown on the monitor should be approximately 25 percent to 33 percent of the size of the monitor's vertical dimension.
2. Adjust the camera's focus and aperture until a clear image is shown on the monitor. When the location is obtained, record the location as instructed in the message window. The binary image is shown on the vision monitor. Ensure that this image clearly shows the circular hole.
3. Adjust the image quality setting as required. The following message will appear on the monitor:

4. Select "yes" from the menu to activate the vision quality utility. Refer to Section 4.5 for instructions. Select "no" to continue the process.
5. Use the pendant to move the robot so that the image of the calibration disk appears at the approximate center of the vision monitor in a different configuration.

   For example, if the robot is in the "lefty" position, change it to the "righty" position. Press REC/DONE to record the location. MAM will automatically continue the calibration process and return to the original configuration. The following message will appear on the monitor:



6. The robot arm moves to the locations that are preprogrammed for the calibration process. Ensure that the image of the circular hole on the calibration disk stays within the monitor boundary during this process. When robot motion is complete, the following message appears:



NOTE

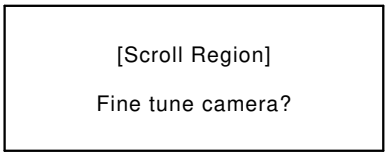
DO NOT MOVE the calibration disk during the calibration process.

7. Select "yes" if the image of the disk stayed within the camera's FOV during the calibration process. The software will start the calibration process. Select "no" if the image of the disk did not stay within the camera's FOV. MAM will reduce the arm's motion and repeat the last two processes until the image of the disk remains within the camera's FOV. The crosshair will enlarge after the first set of pictures is taken. If the crosshair does not increase in size, calibration is unsuccessful.

NOTE

The camera's FOV should not be smaller than 0.75 square inches.

The image of the hole should appear at the approximate center of the vision monitor. This location was taught earlier in the process.



Basic arm-mount camera calibration is complete at this stage. If greater precision is required for the placement (especially for data-driven applications), the following "fifth axis patching" camera tune-up procedure must be executed.

8. Select "yes" from the menu if fine tuning is required. Camera calibration parameters should appear in the menu window. These parameters vary with different camera setups but remain consistent between calibrations. The user is encouraged to record these parameters for future reference.

   The camera tune-up procedure correlates the x-y coordinate feedback from the camera to the actual x-y coordinate at the tip of the end-effector. A laser-reflective scanner mounted at the end of the robot arm is used to scan a through-hole on a metallic plate to determine the end-effector tip location.

   The arm-mount laser scanner must be installed for this procedure. It is located on the camera calibration probe which should be attached to the quill at this point. Set the amplifier on the scanner to "light ON". A reflective plate (a plated-through hole on the PWB can be used) with a diameter greater than 0.125-inch and less than 0.150-inch is required. Use the z-adjustment to focus the laser beam.

9. Enter the following information as instructed:

```
[Message]

Enter arm scanner input signal #
```

10. The arm scanner input signal number is the input signal on the robot controller to which the arm-mount scanner is connected. Enter this signal number after the "==>" prompt. The following message will appear:

```
[Scroll Region]

Move arm until scanner beam approaches the approximate center
of the hole (config. 1)
```

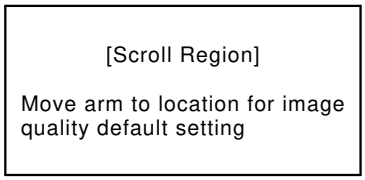
When the above message appears, use the location teaching utility to move the robot arm to a location where the laser beam of the scanner is at the approximate center of the hole. Section 4.3 provides instructions for teaching locations. When complete, the following message will appear:

```
[Scroll Region]

Move arm until scanner beam approaches the approximate center
of the hole (config. 2)
```

11. Repeat the procedure using a different arm configuration. (Rotate the fourth axis of the robot arm.) Ensure that the laser beam of the scanner remains at the approximate center of the hole. Repeat this procedure three times. When complete, the following message will appear:

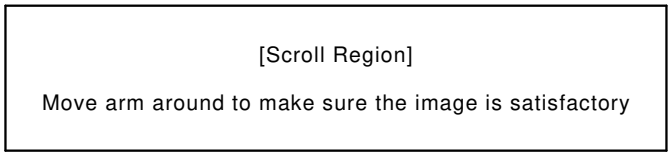
```
[Scroll Region]

Move arm until hole appears at approx center of camera FOV
```

12. Move the robot arm until the hole appears at the approximate center of the camera's FOV. Adjust the image quality if required. Use the vision window set-up utility to enclose the hole within the window shown on the vision monitor. Refer to Section 4.4 for instructions. Verify that the first three motions of the arm cause the laser light to flash on when it hits the edge of the hole and to flash off when it returns to the center of the hole. The robot then moves through 10 scanning repetitions, each at a different calibration probe angle. When calibration is completed the following message appears.



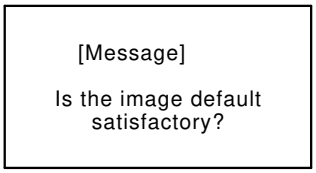
13. The image quality default settings are the parameters, such as threshold, associated with the vision system when pictures of the fiducials are taken during assembly. Place any PWB on the work fixture and move the robot arm until one of the fiducials on the PWB appears on the vision monitor. Record the location and how the image can be adjusted from the pendant. Adjust the image quality until a clear binary image of the fiducial is obtained.

    The image quality default setting is only used for data downloading. The image quality setting (threshold, gain, and offset) determined here will be used as the setting for the fiducial image acquisition. The users are asked to move the arm to an arbitrary location within the working envelope. Then the pendant is activated allowing the user to adjust the image quality until the image on the vision monitor is satisfactory.

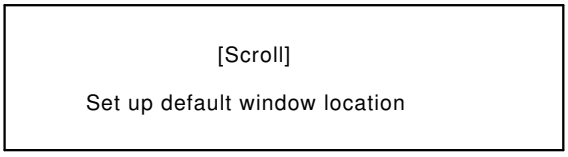


14. At this time the vision system should be showing the image in binary mode. Move the robot arm around so that different locations of the PWB can be seen by the vision system. As the arm is being moved to different locations around the PWB, observe the image and make sure the image is still clear and acceptable for image processing.
15. Terminate this procedure by recording any arbitrary location regardless of the quality of the image.

    For users with Adept vision V+ version 8 or higher, the binary image should appear brighter than normal. This is done to guarantee that the vision will capture the approximate fiducial location under binary mode and that the final fiducial location will be determined under gray scale mode.



16. Select "yes" if the image appears to be satisfactory over the entire work envelope. Select "no" if the image does not appear to be satisfactory. These two steps will be repeated until a satisfactory image is obtained.



17. The default window location is the location on the vision monitor where the download fiducial will be enclosed during the assembly process. Use the pendant to move and change the size of the window only if the window does not already appear in the center of the screen. Press REC/DONE on the pendant to record the window location. The size of the window is not important. The camera calibration process is completed at this point.

    The default threshold and the default window can be re-set when the camera is being modified. The following menu selection sequences are used to change the default threshold setting and the default window location respectively.

```
set-up - camera - modify- [camera ID] - default threshold ...

set-up - camera - modify - [camera ID] - default window ...
```

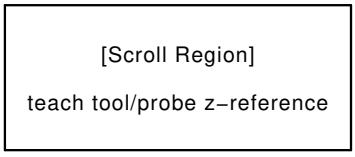
5.1.5.2 Table-Mount Camera Calibration

```
set-up - camera - add ==> [camera ID] - upward looking ...

set-up - camera - modify - [camera ID] - calib ...
```

The table-mount camera calibration calculates the location of the camera with respect to the robot's world coordinate system. The table-mount camera calibration fixture is required for this procedure.

To prepare for the calibration:

1. Estimate the camera's FOV. If using the table-mount camera for surface-mount component correction, estimate the camera's FOV by picking up a component with the robot's end-effector and moving it directly over the table-mount camera. The image of the component will appear on the vision monitor.
2. Move the robot arm up and down in the z-direction until the entire component is shown on the vision monitor. Use this z-height as a reference for camera calibration.
3. Put the calibration fixture on the end-effector. The calibration fixture for the table-mount camera should have a black background with a white circular hole at the center.
4. When the following message appears on the monitor, move the robot and calibration fixture so that is touches the workstation common z-reference.

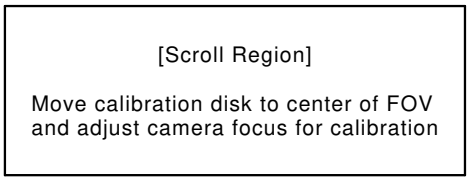


5. Press REC/DONE to record the location. The image of the specified camera will appear on the vision monitor.

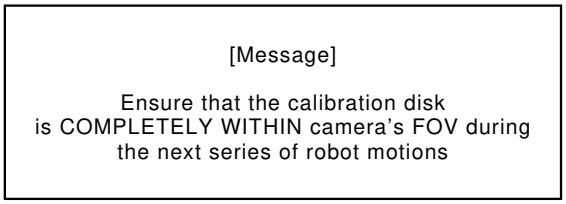
NOTE

The workstation common z-reference data is used later in component correction to compensate for different component heights. This enables the vision system to acquire images at a constant object distance.

6. When the following message appears on the monitor, use the pendant to move the robot until the circular hole of the calibration disk is clearly shown at the approximate center of the camera's FOV. Ensure that the calibration plate is at approximately the same height at the estimated z-height, including the desired dimension for the camera's FOV. The diameter of the hole shown on the monitor should be about 0.33 to 0.25 of the size of the monitor's horizontal dimension. Hold an actual component over the circular hole of the calibration disk and adjust the z-height until the component is zoomed to a maximum image on the vision monitor.



7. Adjust the camera focus and aperture until a clear image is shown on the vision monitor.
8. Press REC/DONE to record the location.
9. Ensure that the binary image clearly shows the circular hole.
10. Select "yes" from the menu to adjust the image quality if required. Refer to Section 4.5 for instructions. Select "no" to continue the process. The robot arm will move through the locations that are preprogrammed for the calibration process.
11. Ensure that the image of the circular hole stays within the monitor boundary. This routine is easier to perform with the overhead lights turned off. The following message appears on the monitor:



When robot motion is complete, the following message appears on the monitor:

```
[Message]

calibration disk stayed WITHIN the camera FOV?
```

12. Select "yes" from the menu if the image of the disk stayed within the camera's FOV during the move. The software will proceed to start the calibration process. Select "no" to repeat the last two series of motions until the image of the disk remains within the camera's FOV.

NOTE

The camera's FOV should not be smaller than 0.75 square inch.

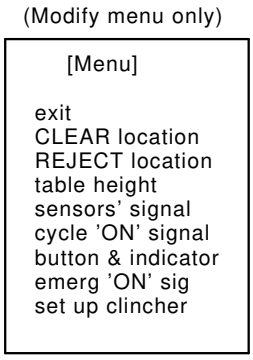
This is a good place to teach fiducial pattern recognition on the Adept Vision System.

5.2 LAYOUT DATA BASE

The layout data base contains the I/O signals and configurations for the workstation hardware. These signals control user interface, lights, indicators, serial ports, and other peripheral equipment.

New layout data can be created or existing data can be modified. If a new layout is created, the existing data will be erased. The layout data base menu is shown in Figure 5–2.

Figure 5–2: Layout Data Base Menu



The signals and hardware in the data base menu are:

- CLEAR location — Robot arm resting location.
- REJECT location — Location where rejected parts are dropped.
- Sensors' signals — Includes the part present sensor (PPS) and gripper displacement sensor (GDS).
- Cycle 'ON' signal — Signals to be turned on during the pick-and-place process cycle. For example, the warning light.
- Button and indicator — Signals for button and indicator used for interfacing with operators.
- Emergency signals — Signals to be turned ON/OFF during emergency interrupt.
- Clincher — Set up clincher for through hole assembly.

The procedure for adding to or modifying the layout data base is described in Section 5.2.1 through Section 5.2.6.

Before continuing, the tool height and the table z-height must be taught.

5.2.1 CLEAR Location

```
set-up - layout - add ...
set-up - layout - modify - CLEAR location ...
```

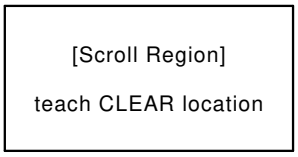
The clear location is where the robot arm rests when there is no active assembly.

NOTE

This location should be taught so that the z-height of the clear location clears all obstacles within the work envelope.

The z-height of the clear location is used when the robot arm is not sure of its current location. For example, when robot motion is stopped due to an emergency, the arm will retract to the z-height of the clear location after the system is reset. This guarantees that the robot arm is clear of obstacles before resuming normal operation.

When teaching the clear location, the following message appears in the scroll region:



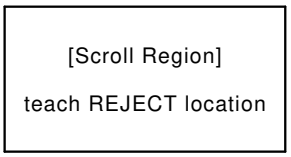
Use the teach utility described in Section 4.3 to teach the clear location.

5.2.2 REJECT Location

```
set-up - layout - add ...

set-up - layout - modify - REJECT location ...
```

The reject location is where the robot arm drops a defective part. A bin should be placed directly below the reject location. When a defective part is detected, the robot arm will move to the reject location and drop the defective part into the bin.

When teaching the reject location, the following message appears in the scroll region:



Use the teach utility described in Section 4.3 to teach the reject location.

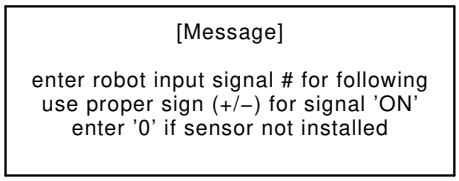
5.2.3 Sensor Signals

```
set-up - layout - add ...

set-up - layout - modify - sensors' signal - part present ==> [PPS]
```

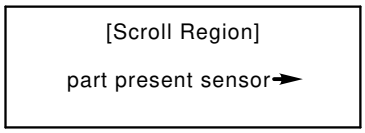
Part Present Sensor (PPS) — The part present sensor detects parts being gripped by the end-effector. For a vacuum type gripper, the PPS is a vacuum sensor. When a part is gripped, low vacuum is detected and successful gripping of a part is signaled.

The PPS is recognized as an input signal number that is sign sensitive. Refer to the *Adept Manipulator System Basic Operation Manual* for further information.

The following message appears in the message window:



Enter the input signal numbers corresponding to these sensors when the following prompt appears in the scroll region:



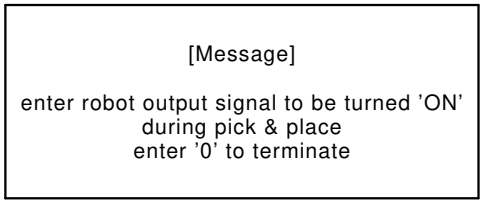
5.2.4 Cycle ON Signal

```
set-up - layout - add ...

set-up - layout - modify - cycle 'ON' signal - add ...
                                             - delete - cycle on sig
                                             - list
```

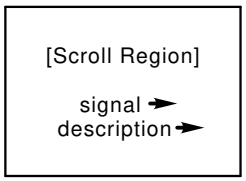
Certain robot output signals can be turned on just before the assembly cycle and turned off just after the assembly cycle is completed. These signals can be used to activate a PWB hold-down device or a warning light during the assembly cycle.

An input signal can also be monitored before the assembly cycle. For example, the robot controller can monitor a sensor to make sure that the board is securely clamped down before the assembly. The output signal and the input signal are executed in the same sequence as they are input.

Enter the signal numbers when prompted by the software. Enter "0" to terminate the signal set-up process. The following instructions appear in the message window:



Enter the output signal number and a brief description of the function of the signal number when the following prompt appears in the scroll region:



Output signals can be added, deleted, or listed by modifying the existing layout data base. Add new signal numbers as described above. To delete a signal number, select the appropriate signal number from the menu. Select "list" to display all signal numbers and descriptions in the scroll region.

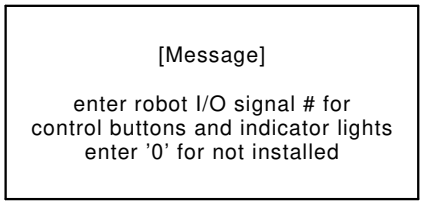
5.2.5 Button and Indicator

```
set-up - layout - add ...

set-up - layout - modify - button & indicator - START
                                              - HOME
                                              - TERM
                                              - RESET
                                              - SAFETY BYP
                                              - EMER lt
                                              - FUNCTION lt
```

The workstation is equipped with an external button box to interface with the operator during normal operation. The button box has four function switches and an emergency push button. All buttons are equipped with indicator lights. The function of these switches are:

1. START — Begins the assembly cycle. Press this button for approximately 3 seconds to activate the assembly cycle.
2. HOME — Recovers the robot from an emergency stop. Power is applied to the robot arm and the arm retracts to the clear location.
3. TERM — Returns control of the robot from the button box to the terminal.
4. RESET —Recovers the robot from an emergency stop. Power is applied to the robot arm, and the arm retracts to the clear z-height and continues the assembly process.
5. SAFETY BYPASS — The SAFETY BYPASS switch is installed remote from the BUTTON BOX. It is used to bypass the safety devices during assembly. If the on/off state of the SAFETY BYPASS indicates that a safety device is being bypassed, the user is required to enter a username and password. The access privilege of the user is checked from the security file on the disk. Only users with technician or system manager access privilege can activate the assembly cycle when a safety device is bypassed.
6. EMER lt — The output signal on the robot that is turned on automatically when emergency condition exists.
7. FUNCTION lt — An output signal used to turn on the indicator lights of the START, HOME, TERM, and RESET buttons. The function light is automatically turned on when there is no active assembly at the workstation.

Enter the signal number when prompted by the software. Enter "0" if the button or light is not installed. The following instructions will appear in the message window:



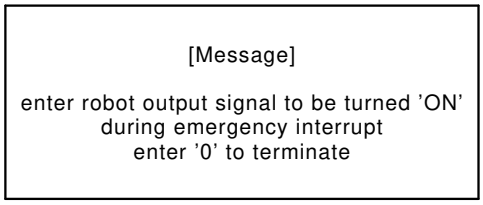
Enter the appropriate signal number after the "==>" prompt.

5.2.6 Emergency ON Signal

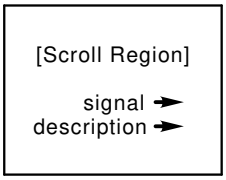
```
set-up - layout - add ...
set-up - layout - modify - emergency 'ON' sig - add ...
                                              - delete - emergency on sig
                                              - list
```

Certain robot output signals must be turned on when an emergency is activated. These signals are restored to their pre-emergency state after recovery from the emergency state.

Enter the signal number when prompted by the software. Enter "0" to terminate the signal set-up process. The following instructions will appear in the message window:



Enter the output signal number and a brief description of its function when the following prompt appears in the scroll region:



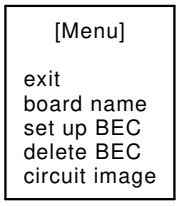
Output signals can be added, deleted, or listed by modifying an existing layout data base. Add new signal numbers as described above. To delete a signal number, select the appropriate signal number from the menu. Select "list" to display all signal numbers and descriptions in the scroll region.

5.3 PRINTED-WIRING BOARD (PWB) DATA BASE

Printed-wiring boards (PWBs) are identified by alphanumeric board names. This data base includes the board error correction (BEC) data as well as basic board locations. PWB data does not generally vary from board to board. PWB data can be added, copied, deleted, modified or listed by selecting "board" from the set-up menu. The board data base menu is shown in Figure 5–3.

```
set-up - board - add ...
set-up - board - modify ...
```

Figure 5–3: PWB Data Base Menu



The following information is stored in the board data base:

- Board name
- Board error correction (BEC) — Contains all the information required to perform a board error correction.
- Thickness — The thickness of the PWB.
- Surface Height — The z-height of the surface of the PWB.

The procedure for adding to or modifying the board data base is described in Section 5.3.1 through Section 5.3.3.

5.3.1 Board Name

```
set-up - board - add ==> [board name]

set-up - board - modify - board name ==> [board name]
```

Identify the PWB with a 10- to 12-character alphanumeric string. For example, the name "vaxcpu" can be used to represent a VAX CPU module.

5.3.2 BEC Set-up

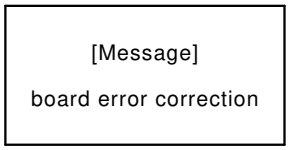
```
set-up - board - add ... * set-up BEC

set-up - board - modify - set-up BEC - camera ID - set-up BEC
```

To incorporate board error correction into the assembly process, the known fiducial locations must be taught using the vision or scanner system. These fiducials are on the same board from which the placement location is calibrated. Refer to Section 5.9. These fiducial locations are used as references during assembly.

NOTE

The nature of the frame correcting algorithm in the robot suggests that the two fiducials with the greatest distance should be taught as fiducial 1 and 2.

When a new board is added to the data base, the following message appears:

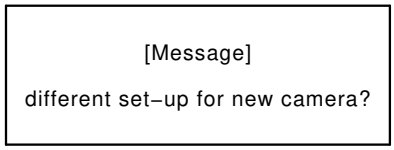


The following steps are required to complete BEC setup.

1. Identify the camera to be used for BEC.

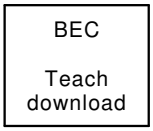
```
set-up - board - add ... * set-up BEC - camera ID ==> [BEC camera]

set-up - board - modify - set-up BEC - camera ID - set-up BEC -
[BEC camera]
```

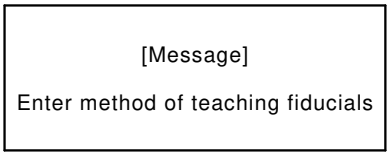
   The selected camera is used to locate the board fiducials during assembly. When modifying BEC data, select the same camera identification number as the previously selected camera. If a different camera is chosen, the following message appears in the message window:



   Select "yes" if the new camera requires different calibration parameters and the previous BEC data is not applicable. A flag is set to ensure that BEC is not carried out during assembly.

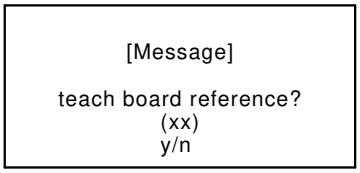
   If "no" is selected, the previously defined parameters are used for BEC. For example, if the wiring of the vision system is changed, but not the camera itself, the previously defined calibration data is used and only the camera number is changed. However, if a new camera is used, new calibration data must be defined.

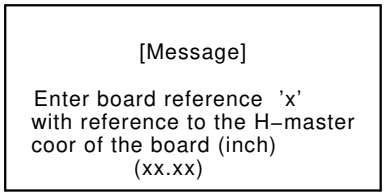


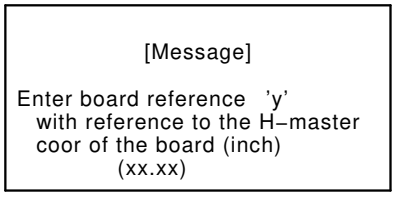


Select a method for fiducial teaching. If "teach" is selected, the user needs to manually teach the locations at which the images are acquired. The MAM software prompts the user to move the robot arm to these locations. Board data must be downloaded at this point in order to download placement data. Refer to the Vision Window Set-up Utility in Section 4.4 for details. After the fiducials have been taught, clear the work envelope and the robot arm moves to these locations to acquire the image of the fiducials. These images provide the robot a known good board reference frame and placements are corrected with respect to this frame.

If "download" is selected, the board fiducial location is then designated by coordinate data with respect to the H-master frame. In order to capture the board fiducial location, the station fiducial described in the layout data base is used. The next three messages should appear sequentially in the message window:



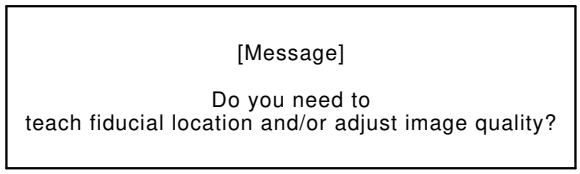




The numbers that appear in the parentheses are the numbers previously assigned to the variables. If the variables were not defined previously, the parentheses will

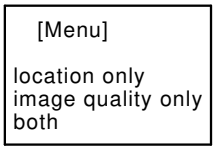
not be shown in this message window. The 'x', 'y' coordinates of the station fiducials are defined with reference to the H-master frame of the board. The coordinate of the station fiducials can be obtained by pinning the board in the assembly position and measuring the locations of the station fiducial from the H-master zero of the board. For example, if the "A" hole is used as the station fiducial, the location of the "A" hole with reference to the H-master coordinate should be the 'x', 'y' coordinate of the station fiducials as well.

2. Teach the camera the locations where the board fiducial's images are acquired; adjust the image quality.



Select "no" to use previously defined fiducial parameters, image, and location. If these parameters are not defined in the data base, the message will re-appear in the message window.

Select "yes" to define new fiducial parameters and/or location and image information. The following options appear on the menu:

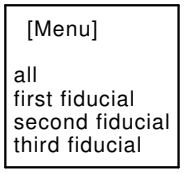


NOTE

In order to change the image quality on downloaded data, go to the camera menu and adjust the threshold.

The user can teach the fiducial locations, adjust the vision image quality, or both. If "location" is selected, the robot arm must be moved to the location where the image is to be acquired. The vision window utility is then used to define the fiducial location. If "image" is selected, clear the work envelope and the robot arm will move to the previously defined image acquiring location. The image quality utility is then used for image adjustment. If "both" is selected, the new image acquiring location must be taught and the image quality must be adjusted. Refer to Section 4.5 for instructions on adjusting the image quality.

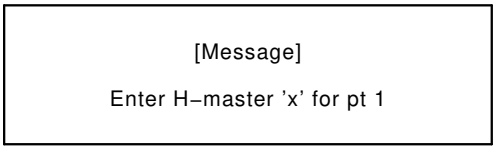
The next menu defines which fiducials will be affected:

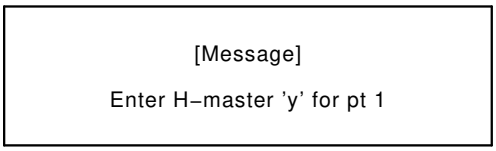


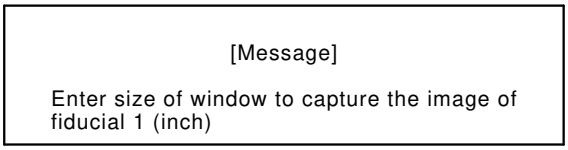
Select "all" to re-teach the image acquiring locations of all three fiducials. Select "first", "second" or "third" to re-teach any one of the three board fiducial's image acquiring locations.

If "teach" was selected previously then the user needs to physically move the arm until the fiducial can be seen on the monitor. See Section 4.4 for further information.

If "download" was selected previously, the following sequence of messages appears in the message window:







In this example, enter both the H-master coordinate 'x', 'y' of fiducial 1 and the size of the vision window to capture the image. The size of the window is the dimension of the square window of the vision system within which the image is being processed. Any features outside of the window will be disregarded. The suggested setting for a 0.04-inch diameter fiducial is 0.07 inch.

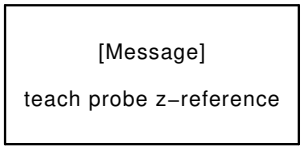
The image quality such as threshold, gain, and offset were set as defaults during camera calibration. See Section 5.1 for further information.

5.3.3 Surface Height

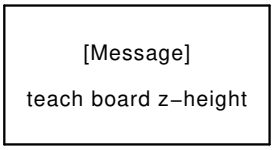
```
set-up - board - add ... * teach surface height
set-up - board - modify - surf ht * teach surface height
```

The surface height of the board, combined with the component height, the component grip offset, and the tool z-reference determines the absolute z-height of all placements a particular board.

The probe z-reference determines the length of the tool to be used for teaching the z-height of the board. When the following message appears on the monitor, move the robot arm until the tip of the tool touches the workstation common z-reference location.



When complete, the following message will appear:



To teach the board z-height:

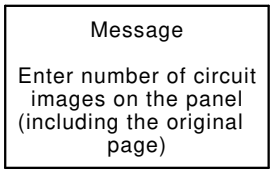
1. Place the PWB in its final assembly position.
2. Move the robot arm until the tip of the tool touches the surface of the board.
3. Press REC/DONE to record the location.
4. Clear the work envelope.

5.3.4 Circuit Image

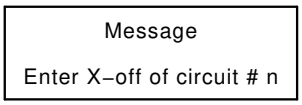
```
set–up – board – modify – circuit–image
```

The circuit image is defined as the identical circuits on one single PWB. The MAM software always assumes that there is one circuit image on the PWB. If there is more than one circuit image on a single PWB, the offset of the image should be entered.

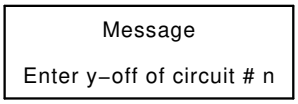
When setting up multiple circuit images, the user needs only to identify board fiducials and placement loction on one circuit image as the "primary image". The robot will automatically place components on other images based on the "x-y" offset centered by the user. The offset coordinate used should be the same as the coordinate used for board fiducials. (The offset is the distance between two identical features on the circuit.)



Enter the number of circuit images on the panel including the original image, for example, if there are two identical circuits on the panel, then the number of images should be "2".



Depending on the number of images, "n" ranges from 1 to the total number of images on the PWB. Enter the x-offset of the image with respect to the primary images.



Enter the y-offset of the image with the primary image, for example, if positive x is pointing to the right and positive y is pointing upward and there is a total of 4 images on the panel with 2 images per row, the lower left image is selected to be the primary image, and each image is offset 5 inches in "x" and 2 inches in "y". Then the offset value for the images are:

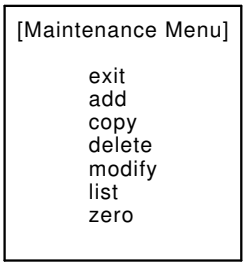
```
(0,0)     (5,0)     (0,3)     (5,3)
```

5.4 PROCESS DATA BASE

The process data base contains instructions to direct the robot's action. Each "process" defines a single pick-and-place cycle including board error correction, local error correction, and component error correction.

Each pick-and-place cycle must be organized in a logical procedural flow. For example, a part must be picked up before it can be placed. Groups of processes, however, can be defined in any order.

Procedural flow menus are provided in MAM to help organize the building of each process. When building a process, the process window displays the current process being built. The following headings show an example of a process that uses all available options on the workstation. The messages that appear in the process window are provided to demonstrate the interactive nature of process building. Process building is invoked by selecting the following menu items from the Maintenance menu.



To add a process:

```
set-up - process - add ==> [process name]...
```

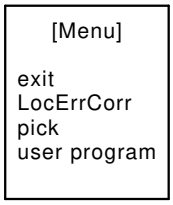
The process name is a numeric identification number. Enter the process identification number after the "==>" prompt in the scroll region.

To replace or modify a particular process, delete the process and then use the same process identification number to add to the data base.

5.4.1 Process I Menu

After entering the process identification number, Process I menu appears on the monitor. Refer to Figure 5–4.

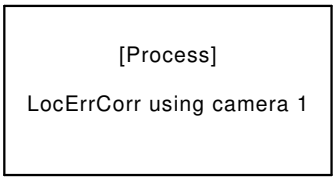
Figure 5–4: Process I Menu



Select "exit" to exit process building without adding a new process to the data base. The following steps must be followed sequentially:

1. Select "LocErrCorr" if local error correction is required. If local error correction is not required, proceed to step 2.

   When "LocErrCorr" is selected, a flag is set to inform MAM that the camera should be used to locate the fiducials for placement, and that correction should be made to the final placement location according to the camera image. The identification of the camera used, previously defined in the placement data base, appears in the process window as follows:



2. Select "pick" from the menu window. All part numbers that have been defined in the part data base will appear in the menu window. Use the arrow keys to highlight the desired part number and press RETURN. The Process II menu (see Section 5.4.2) will appear in the menu window and the process window will display the part number to be picked and the feeder associated with that part. For example:

```
[Process]

LocErrCorr using camera 1 pick part no 12–34567–89
from feeder waffle1
```

The "program" option is not required but can be selected at any stage during process building to call out a user-defined procedure. These procedures must be written as V+ subroutines. When "program" is selected, the user is prompted to enter the V+ subroutine name that contains the special procedure. Enter the subroutine name after the "==>" prompt in the scroll region.

For example, a user-defined procedure to perform component inspection can be called out and executed before picking a part. The following process window shows a special procedure, "inspect," that is inserted before the pick procedure:

```
[Process]

LocErrCorr using camera 1 program inspect pick
part no 12–34567–89 from feeder waffle1
```

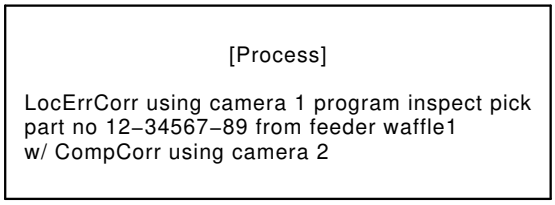
5.4.2 Process II Menu

Figure 5–5 shows the Process II menu.

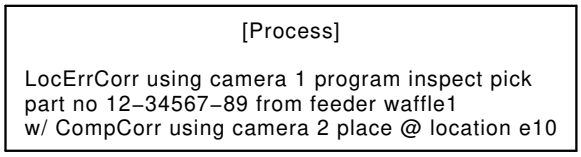
Figure 5–5: Process II Menu

```
[Menu]

exit
FdCorr
CompCorr
RTG
place
user program
pot dunk
```

If component correction is required , "CompCorr" must be selected before "place". When "CompCorr" is selected, a subroutine is called out to move the part to the component correction camera (previously defined in the feeder data base) and to calculate the component offset for the final placement location. The process window will display the following:


[Process]
LocErrCorr using camera 1 program inspect pick
part no 12–34567–89 from feeder waffle1
w/ CompCorr using camera 2

When "place" is selected from the menu, the menu window displays all placement locations that have been defined in the placement data base. Use the arrow keys to highlight the desired placement location. The Process III menu (see Section 5.4.3) appears in the menu window and the process window displays the following:

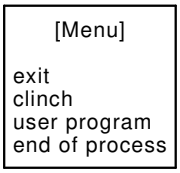

[Process]
LocErrCorr using camera 1 program inspect pick
part no 12–34567–89 from feeder waffle1
w/ CompCorr using camera 2 place @ location e10

Select "exit" to terminate the process building without adding a new process to the data base. "Program" can be selected at any stage to insert a user-defined procedure. Refer to Section 5.4.1 for instructions.

5.4.3 Process III Menu

Figure 5–6 shows the Process III menu.

Figure 5–6: Process III Menu



Select "clinch" if clinching is required. "Program" can be selected at any stage to insert a user-defined procedure. Refer to Section 5.4.1 for instructions. Select "exit" to terminate process building without adding a new process to the data base.

When process building is complete, the user MUST select "end of process" from the Process III Menu. If "end of process" is not selected, the process is open-ended and will not be written to the process data base.

```
[Process]

LocErrCorr using camera 1 program inspect pick
part no 12–34567–89 from feeder waffle1
w/ CompCorr using camera 2 place @ location e10
end
```

5.5 PART DATA BASE

The part data base provides pointers within the MAM data structure that direct the robot to pick up a specific component from a specific feeder. For example, part number "27-25797-01" is pointed to a component type with 64 leads and 0.050-inch lead spacing that is being placed at feeder "feeder1".

Part numbers can be added, copied, deleted, modified, listed or zeroed by selecting "part" from the set-up menu. Creation of a new part number can also be invoked at different points within the program as required after selecting "modify" and a specific part number. The part data base menu is shown in Figure 5–7.

Figure 5–7: Part Data Base Menu

```
[Menu]

exit
part no
comp
feeder
```

The following information is stored in the part data base:

- Part number — Part number on the component.
- Component — component name previously defined in the component data base.
- Feeder — Feeder name previously defined in the feeder data base.

The procedure for adding to or modifying the part data base is described in Section 5.5.1 through Section 5.5.3.

5.5.1 Part Number

```
set-up - part - add ==> [part number]

set-up - part - modify - part no. ==> [part number]
```

A 10- to 12-character part number is used to identify parts.

5.5.2 Component Type

```
set-up - part - add ==> [part number] - component type

set-up - part - modify - [part number] - comp - component type
```

The component type corresponds to the component name previously defined in the component data base. Select the appropriate component type from the menu.

5.5.3 Feeder

```
set-up - part - add ... - [feeder ID]

set-up - part - modify - part number  - [feeder ID]
```

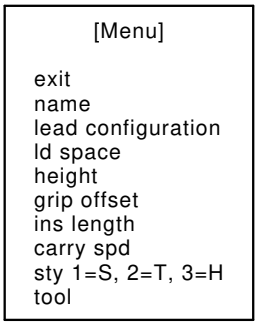
The feeder corresponds to the feeder name previously defined in the feeder data base. Select the appropriate feeder from the menu.

5.6 COMPONENT DATA BASE

Component data is stored in the component data base and includes the basic physical geometry of each type of component. For example, a 164-lead surface-mount cerquad device has 41 leads per side and a component height of approximately 3.7 mm (without heat sink). Tool #2 is used to pick up this component.

Component data can be added, copied, deleted, modified, listed, and zeroed by selecting "component" from the set-up menu. New component data can also be created at different points in the program if required. Figure 5–8 shows the component data base menu.

Figure 5–8: Component Data Base Menu



Component information includes:

- Name — Name of the component
- Lead configuration — Number of leads on each side of the component
- Lead spacing — Distance between the centerline of two adjacent leads
- Height — Distance from the component seating plane on which the leads rest to the surface (top) of a component or the height of a heatsink
- Grip offset — Dimension that determines the "depth" of the grip for parallel gripper

- Carrying speed — Speed of the robot arm while carrying the component on the end-effector
- Style — Type of component used, either surface mount, through hole, or heatsink
- Tool - Tool on the end-effector to be used for component picking

The procedure for adding to or modifying the component data base is described in Section 5.6.1 through Section 5.6.8.

5.6.1 Component Name

```
set-up - component - add ==> [component name]

set-up - component - modify - name ==> [component name]
```

Identify components with a 10- to 12-character alphanumeric string. For example, the name "64p50mnh" can be used to represent a 64-pin 0.050-inch pitch cerquad with no heatsink.

5.6.2 Lead Configuration

```
set-up - component - add ==> [component name] ==> [ld count sd 1]
                                                   [ld count sd 2]
                                                   [ld count sd 3]
                                                   [ld count sd 4]

set-up - component - modify - [component name] - lead configuration

                            - ld count sd 1 (n1) ==> [ld count sd 1]
                            - ld count sd 2 (n2) ==> [ld count sd 2]
                            - ld count sd 3 (n3) ==> [ld count sd 3]
                            - ld count sd 4 (n4) ==> [ld count sd 4]
```

Lead count information is only required if component correction and/or component inspection will be used for component placement. Currently, MAM only supports components with four sides and with equal lead counts on each side.

Side 1 is determined by the component pin 1 marking. Sides 2, 3, and 4 are the adjacent sides progressing clockwise when viewed from the top of the component.

5.6.3 Lead Spacing

```
set-up - component - add ==> [component name] ==> ... ==> [lead
spacing]

set-up - component - modify - [component name] - ld space ==>
[lead spacing]
```

The component lead spacing is the distance between the center of the leads (in mils). Lead spacing information is only required if component correction and/or component inspection is used for component placement. Currently, MAM only supports components with equal lead spacing on all four sides.

5.6.4 Component Height

```
set-up - component - add ==> [component name] ==> ... ==>
[component ht]

set-up - component - modify - [component name] - height ==>
[component ht]
```

The component height (mm) is the height of the component when viewed from the side. For example, the component height of a surface-mount cerquad device is measured from the seating plane of the component to the top ceramic surface of the component.

5.6.5 Grip Offset

```
set-up - component - add ==> [component name] ==> ... ==> [grip
offset]

set-up - component - modify - [component name] - grip offset ==>
[grip offset]
```

The grip offset defines the z-height dimension for components that require gripping. When the robot arm picks up a component, the arm moves the tip of the gripper to a position lower than the top of the component by a dimension equal to the grip offset dimension. If the vacuum gripper is used, the grip offset is equal to "0". If through-hole components are used, the insertion length is equal to the value of the component to be pressed into the board. For surface mount placement the insertion length is equal to "0".

5.6.6 Carrying Speed

```
set-up - component - add ==> [component name] ==> ... ==>
[carrying speed]

set-up - component - modify - [component name] - carry spd ==>
[carrying speed]
```

The component carrying speed is defined in millimeters per second (mmps). This speed is most accurate when the monitor speed is set at 100% and is activated whenever the component is on the robot's end-effector during assembly. Since the component carrying speed is not guaranteed for individual robots, test the speed setting for different applications. The component carrying speed for surface-mount components using the vacuum gripper is typically between 1000—2000 mmps. A carrying speed of up to 3000 mmps can be used for through-hole components using the parallel gripper. Refer to the *Adept Manipulator System Basic Operation Manual* for further information on monitor speed.

5.6.7 Component Style

```
set-up - component - add ==> [component name] ==> ... - surface-mount
                                                      - through-hole

set-up - component - modify - [component name] - style - surface-mount
                                                       - through-hole
```

MAM supports both surface-mount and through-hole components. The major difference between the two styles are force sensing and departing speed during component placement.

- Force sensing — For surface-mount components, the signal from the force sensor triggers the robot to release the component. For through-hole components, the force sensor signals insertion problems. A search routine is activated until the component is inserted.
- Departing — For surface-mount components, the robot departs slowly to prevent component "sticking" after the component is released. For through-hole components, the robot arm departs at system speed after the component is released.

5.6.8 Component Carrying Tool

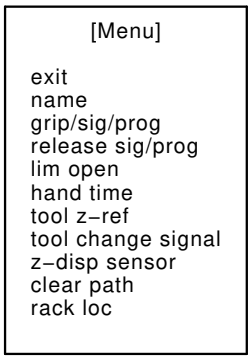
```
set-up - component - add ==> [component name] ==> ... ==>
[carrying tool]

set-up - component - modify - [component name] - tool -
[carrying tool]
```

Each component is assigned a tool/gripper. The tool used to pick up the component is identified by its identification number.

5.7 TOOL DATA BASE

Tool data includes the physical geometry of the end-effector (gripper) and the binary signals used to operate the tool. Tool data can be added, copied, deleted, modified, listed, or zeroed by selecting "tool" from the set-up menu. Tool creation is invoked at several points in the program as required. Figure 5–9 shows the tool data base menu.

Figure 5–9: Tool Data Base Menu



The signals and hardware supported by MAM are:

- Name — This is the name assigned to the tool; use an alphanumeric with a maximum of 12 characters.
- Grip/signal/program — A signal number or subroutine program to activate the gripping action of the end-effector.
- Release name signal/program — A signal number or subroutine program to activate the release action of the end-effector.
- Limit opening — A signal number to limit the opening action of the parallel gripper.
- Hand time—A delay in robot motion that occurs after the grip and release signals have been activated.
- Tool z-reference — Allows the user to change the length of a tool without re-teaching the pick-up and placement locations.
- Tool change signal — Three binary input signals on the robot are used to identify the tool currently on the arm.
- Z-dispenser sensor — The signal number of the gripper.
- Clear path — Location that define a clear path for the robot during tool change.
- Rack location — The location of the tool rack.

The procedure for adding to or modifying the tool data base is described in Section 5.7.1 through Section 5.7.10.

5.7.1 Tool Name

```
set-up - tool - add ==> [tool ID]
set-up - tool - modify - [tool ID] - name ==> 'new name'
```

Name is an alphanumeric string, not to exceed 12 characters, used to identify a particular tool on the robot.

5.7.2 Grip/Signal/Program

```
set-up - tool - add ==> [tool ID] ==> [grip/sig/prog]

set-up - tool - modify - [tool ID] - grip/sig/prog
==> [grip/sig/prog]
```

Enter a numeric grip signal number to activate the associated binary output signal. The grip signal number is the robot's binary output signal that is activated when an object is to be picked up and deactivated when the object is to be released. This signal can be used to close the parallel gripper or turn on the vacuum of the vacuum pick-up device. For the Adept Robot, this signal ranges from 1 to 16 for a 16 binary output configuration. Refer to the *Adept Manipulator System Basic Operation Manual* for further information.

The grip signal number can be replaced by an alphanumeric V+ subroutine name that is represented by a character string. If a number is input for the grip signal, the associated binary output signal will be activated. Otherwise, the signal will be treated as a V+ subroutine and the subroutine will be executed.

For example, if a V+ routine named "close" is written to control the gripping action of a custom made gripper, enter the character string "close" instead of a numeric grip signal. When gripping is required during the assembly process, this routine will be executed.

5.7.3 Release Signal Number/Program

```
set-up - tool - add ==> [tool ID ... ] ==> [release sig/prog]

set-up - tool - modify - [tool ID] - rel sig/prog ==> [release
sig/prog]
```

Enter a numeric release signal number to activate the the associated binary output signal. The release signal number is the binary output signal to be activated when an object is released by the robot and deactivated when an object is picked up. This signal can be used to open the parallel gripper or turn off the vacuum of the vacuum pick-up device. For the Adept Robot, this number ranges from 1017 to 1032 for a 16 binary output and 16 binary input configuration. Refer to the *Adept Manipulator System Basic Operation Manual*.

The release signal number can be replaced by an alphanumeric V+ subroutine name represented by a character string. For example, if a V+ routine named "open" is written to control the release of a custom-made gripper, enter the character string "open" instead of a numeric grip signal. When release is required during the assembly process, this routine will be executed.

5.7.4 Limit Open Signal

```
set-up - tool - add ==> [tool ID] ... ==> [limit open sig]

set-up - tool - modify - [tool ID] - lim open ==> [limit open sig]
```

The "limit open" option supports the Robothand finger gripper and other grippers with compatible functions. This option reduces the opening of the parallel gripper's fingers to a small displacement (0.05 inches for the Robothand parallel gripper).

Enter a number to represent the binary output signal of the robot. For the Adept Robot this number ranges from 1 to 16 for a 16 binary output configuration. Refer to the *Adept Manipulator System Basic Operation Manual* for further information. The "limit open" option is activated when the binary output signal is activated. Enter "0" if this option is not required.

5.7.5 Hand Time

```
set-up - tool - add ==> [tool ID] ... ==> [hand time]
set-up - tool - modify - [tool ID] - hand time ==> [hand time]
```

The hand time is a delay in robot motion that occurs after the grip and release signal have been activated. This feature is used when extra time is needed for opening and closing the gripper. For example, the hand time for the vacuum pick-up device reduces the "sticking" problem caused by the compliance of the gas.

Enter the number of seconds required for the hand time delay when prompted by the software.

5.7.6 Tool Change Signal

```
set-up - tool - add - [tool ID] ... ==>[tool change signal 1],
[tool change signal 2], [tool change signal 3], [cut-off signal],
[tool rack signal]

set-up - tool - modify - [tool ID] - ID signal 1
                                     ID signal 2
                                     ID signal 3
                                     cut-off signal
                                     tool rack
```

There are five tool change signals.

ID Signal 1, 2, 3 — The three binary signals identify the tool currently on the robot arm. The user should wire the individual tool to different combinations of "on" and "off". The on/off state of the signal and the signal number used is identified here. For example, if the tool on the arm is wired so that signal 1001 is "on", signal 1002 is "off", and signal 1003 is "on" then the three identification signals are "1001", "-1001", and "1003". If "0"s are used in the signal, the program ignores the signal checking and prompts the user to input the name of the tool currently on the arm.

Main Cut-off Signal — If a non-zero number is input, the program turns off the binary signal before releasing the tool and turns on the binary signal after engaging the new tool.

Rack Signal\bold) — The program checks this binary signal before the tool is returned to the rack.

5.7.7 Gripper Z-Displacement Sensor

```
set-up - tool - [tool ID] ... ==> [sensor signal number]

set-up - tool - [tool ID] - z-dispenser sensor ==> [sensor signal
number]
```

The sensor detects the displacement of the gripper due to compression in the Z-direction when placing a component on a PWB.

5.7.8 Tool Z-Reference

```
set-up - tool - add ==> [tool ID] ... * teach tool z-reference

set-up - tool - modify - [tool ID] - tool z-ref  * teach tool
z-reference
```

The tool z-reference allows the user to change the length of a tool, such as the tip length of the vacuum pick-up device, without re-teaching the pick-up and placement locations.

The workstation common z-reference location is used to define the z-tool reference. Follow the instructions below when the teach utility is invoked.

1. Use the pendant to move the robot arm so that the tip of the tool touches the workstation common z-reference location. If a low compliance spring-loaded tool is used, ensure that compression is not induced during the teaching process. Since the tool comes in contact with a stationary object during the teaching procedure, use extra care to prevent damage to the tool.
2. Press REC/DONE to record the location.
3. Clear the work envelope.
4. Press RETURN to terminate the process.

Refer to Section 4.3 for location teaching instructions.

5.7.9 Tool Rack Approach Height

The tool rack approach height is the distance that the robot arm departs after dropping the tool onto the rack and before the robot picks up the tool from the rack. (The suggested value is 45 mm.) The user should make sure that this distance is sufficient for the gripper exchange unit to clear the tool on the rack.

5.7.10 Number of Clear Path Locations

```
set-up - tool - [tool ID] ... [number of path locations]
set-up - tool - [tool ID] - clear path * teach clear path locations
```

The clear path locations are locations through which the robot arm moves when exchanging tools. These locations provide an obstacle-free path for the robot.

Enter a positive integer if clear path locations are required. MAM prompts the user to teach these locations. The robot arm moves through the locations in the sequence in which they are taught. The robot does not "break" along the clear path. **It is recommended that the last clear path location be located directly above the tool rack for the "top down" tool exchange rack.**

5.7.11 Rack Location

```
set-up - tool - [tool ID] ... * teach rack location
set-up - tool - [tool ID] - rack loc * teach rack location
```

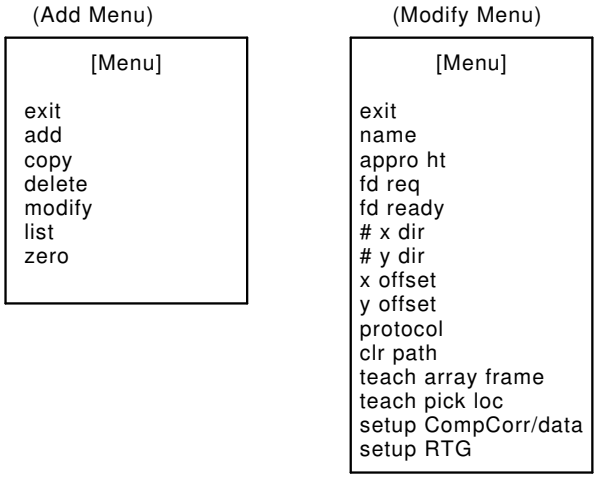
The tool rack location identifies where the robot picks up and releases the tool.

5.8 FEEDER DATA BASE

Feeder data includes the basic locations and control signals associated with a particular type of feeder.

Feeder data can be added, copied, deleted, modified, or listed by selecting "feeder" from the set-up menu. New feeder data can also be created as required. The feeder data base menu is shown in Figure 5–10.

Figure 5–10: Feeder Data Base Menu



The following information is stored in the feeder data base:

- Name — Alphanumeric identifier of the feeder
- Approach height — The distance between the component pick up location and the robot arm before and after the component is picked
- Feeder Request signal/program — Not implemented
- Feeder Ready signal — Not implemented
- Style — Feeders are set up in MAM as "n × m" matrix trays. The style of a feeder includes the number of components and the distance between the adjacent "pockets" in each orthogonal direction of the matrix tray

- Pick location — Contains the pick-up location of the feeder. This location consists of the feeder seating plane height on which the leads of the component rest, and the x-y coordinates of the pick up location
- Set up Component Correction — The component image acquiring location is stored here

The procedure for adding to or modifying the feeder data base is described in Section 5.8.1 through Section 5.10.

5.8.1 Feeder Name

```
set-up - feeder - add ==> [feeder ID]
set-up - feeder - modify - name ==> [feeder ID]
```

Enter a feeder identification name after choosing the above menu options. For example, the name "waf1" can be used to represent an "n x n" array feeder.

5.8.2 Approach Height

```
set-up - feeder - add ==> [feeder ID] ==> [approach height]

set-up - feeder - modify - [feeder ID] - appro ht ==>
[approach height]
```

The feeder approach height (mm) defines the location where the robot arm pauses momentarily before picking up a component from the feeder. This location is directly above the component pick-up location at a distance equal to the feeder approach height. The feeder approach height must be greater than or equal to the component grip offset or the tool may jam the component in the feeder during the pick-up procedure. Refer to Section 5.6.5 for further information on the component grip offset.

5.8.3 Request Signal/Program

```
set-up - feeder - add ==> [feeder ID] ... ==> [feeder request sig]
set-up - feeder - modify - [feeder ID] ==> [feeder request sig]
```

The requested signal number is the binary output signal that is activated after the robot picks up a component from the feeder. This allows the robot to signal the feeder to advance (index). For the Adept Robot this signal number ranges from 1 to 16 for a 16 binary output configuration. Refer to the *Adept Manipulator System Basic Operation Manual* for further information. If the request signal is represented by a number, the associated binary output signal represented by the number will be activated and then deactivated after a moment.

The requested input signal can be replaced by an alphanumeric V+ subroutine name. For example, if a V+ subroutine named "advance" is written to control the advancement of a custom-made feeder, enter the character string "advance". When this string is encountered during the assembly process, the V+ subroutine "advance" is executed.

NOTE

The request signal feature is not implemented in MAM version 3.0.

5.8.4 Feeder Ready Signal

```
set-up - feeder - add ==> [feeder ID] ... ==> [feeder ready sig]
set-up - feeder - modify - [feeder ID] - fd rdy ==> [feeder ready sig]
```

The "feeder ready" signal is a binary input signal through which the robot monitors component feeding. The state of the binary input signal is determined by the associated feeder. A "set" condition indicates that the component is at the feeder's pick-up location and is ready to be picked up by the robot arm. A "reset" condition indicates that the component is not at the feeder's pick up location and is therefore not ready to be picked up by the robot arm.

MAM checks this input signal before picking up the component from the feeder. If the signal is "set", the robot arm will proceed to pick up the component from the feeder. If the signal is "reset", the robot arm will pause until the signal is changed to "set". For the Adept Robot, the signal numbers range from 1017—1032 with 16 binary output and 16 binary input configurations. Refer to the *Adept Manipulator System Basic Operation Manual* for further information.

5.8.5 Number of Components in X- and Y-Direction

The feeder is treated as "n $\times$ m" matrix which allows component pick up at multiple locations on a two dimensional plane. The letters "n" and "m" are the number of components in the direction of the two orthogonal x and y axes. The direction of the x and y axes are defined during feeder frame teaching.

The following menu sequence is used to define the total number of components in the "x" direction:

```
set-up - feeder - add ==> [feeder ID] ... ==> [#x dir]
set-up - feeder - modify - [feeder ID] - # x dir ==> [# x dir]
```

The following menu sequence is used to define the total number of components in the "y" direction:

```
set-up - feeder - add ==> [feeder ID] ... ==> [# y dir]
set-up - feeder - modify - [feeder ID] - # y dir ==> [# y dir]
```

Identify the internal or external index for the feeder at this point. With an internal index the robot keeps track of each component location in the feeder. With an external index the feeder moves the component to the same location each time for pickup.

5.8.6 X-Offset

```
set-up - feeder - add ==> [feeder ID] ... ==> [# x dir] {if
# x dir > 1 then} ==> [x offset]

set-up - feeder - modify - [feeder ID] - x offset ==> [x offset]
```

The x-offset is the distance (mm) measured between two adjacent component pick-up locations in the x direction. This entry is bypassed when entering new feeder data if the total number of components in the x direction is less than or equal to one.

5.8.7 Y-Offset

```
set-up - feeder - add ==> [feeder ID]... ==> [# y dir]
{if # y dir > 1 then} ==> [y offset]

set-up - feeder - modify - [feeder ID] - y offset ==> [y offset]
```

The y-offset is the distance (mm) measured between two adjacent component pick-up locations in the y direction. This entry is bypassed when entering new feeder data if the total number of components in the y-direction is less than or equal to one.

5.8.8 Frame Teaching

```
set-up - feeder - add ==> [feeder ID]... ==> [# y dir]
{if # y dir > 1 then} ==> [y offset] - vision * teach feeder frame

set-up - feeder - modify - [feeder ID] - teach array frame - vision *
teach feeder frame
```

The vision system is used to determine the location of the three dowel pins, or any fiducials on a feeder that define the feeder frame, in order to establish orthogonal "x" and "y" coordinates. The following steps are required to teach the feeder frame. Instructions for this procedure are shown in the scroll region of the monitor. Refer to Section 4.4 for instructions on setting up the vision window.

1. Specify the camera to be used for locating the dowel pins on the feeder. The identification numbers of all previously defined cameras are shown in the menu. Select the appropriate camera identification number from the menu.
2. Capture the dowel pin that represents the origin of the frame. Move the robot arm until this dowel pin appears at the approximate center of the camera's FOV. Set up the vision window so that the center dowel pin is entirely enclosed by the vision window. Press REC/DONE to record the location.
3. Capture the x-reference dowel pin location to set up the positive x-axis. Move the robot arm along the length of the feeder until the vision monitor shows the x-reference dowel pin at the approximate center of the camera's FOV. Set up the vision window so that the x-reference dowel pin is entirely enclosed by the vision window. Press REC/DONE to record location.

4. Capture the y-reference dowel pin location to set up the positive y-axis. Move the robot arm along the length of the feeder until the vision monitor shows the y-reference dowel pin at the approximate center of the camera's FOV. Set up the vision window so that the y-reference dowel pin is entirely enclosed by the vision window. Press REC/DONE to record the location. This entry is bypassed when entering new feeder data if the total number of components in the x-direction is less than or equal to one.
5. Teach the clear location.

5.8.9 Feeder Pick Location

```
set-up - feeder - add ==> [feeder ID] ...

set-up - feeder - modify - [feeder ID] - teach array frame
* teach pick location
```

The feeder pick location is the location where the component is picked from the feeder. The location information has two variables:

a. Component Seating Plane Z-Reference — The z-reference of the feeder pick location is the z-height of the plane on which the pins of the component rest. The z-reference can be taught by attaching a probe to the end of the robot arm. The following prompt appears in the scroll region:

[Scroll Region]
teach probe z–reference

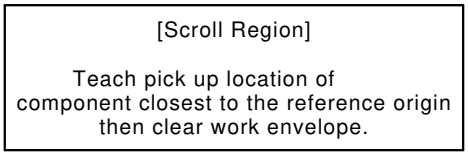
Move the robot arm until the probe or tool touches the workstation common z-reference. Press REC/DONE to record the location.

[Scroll Region]
use probe to teach z–height of feeder's seating plane

Move the robot arm until the probe touches the component seating plane z-reference. Press REC/DONE to record the location.

The component seating plane, z-reference, component height, and component grip offset information provides the final z-height for component pick-up. This approach allows changes in tool length, feeders, or component without re-teaching the pick-up location.

b. x,y Location — This location determines the x,y plane location of the component pick-up location. The following instructions appear in the scroll region:



Move the robot arm until the probe is at the component pick-up location. If using an array feeder (such as waffle pack), teach the pick-up location closest to the center (origin) of the feeder frame.

NOTE

The height of the pick-up location has no relation to the final pick-up location. The z-height of the pick-up location is determined by the previously defined z-reference of the seating plane.

Feed Location - Seating Plane

The seating plane z-height or the pick location of the feeder can be taught independently when modifying the feeder data base. The menu selection sequence to re-teach the feeder seating plane or the pick location is shown as follows:

```
set-up - feeder - modify - [feeder ID] - teach pick location -
seating plane - shift ==>[shift]
              -teach * teach feeder seating plane
```

When "shift" is selected, enter the magnitude of the shift in mm. Enter a positive number to move up and a negative number to move down. When "teach" is selected, move the robot arm to the seating plane as described in the previous section.

5.8.10 Component Correction

```
set-up - feeder - add ==> [feeder ID] ...
set up for component correction - yes - vision

set-up - feeder - modify - [feeder ID] - set up CompCorr - vision
```

If component correction is required for pick-and-place, hardware locations (such as the table-mount camera) must be defined in the feeder data base. The component correction process defines the locations and camera parameters to be used during component correction. The following set-up procedure is used:

1. Approach Height:

```
set-up - feeder - add ==> [feeder ID] ... ==> [approach height]

set-up - feeder - modify - [feeder ID] - appro ht ==> [approach
height]
```

The component correction approach height (mm) is the location where the robot arm pauses before moving to the location where the vision image is acquired. This location is usually directly above where the vision image is acquired..

2. Camera Identification:

```
set-up - feeder - add ==> [feeder ID] ... - camera ID

set-up - feeder - modify - [feeder ID] - vision - camera ID
```

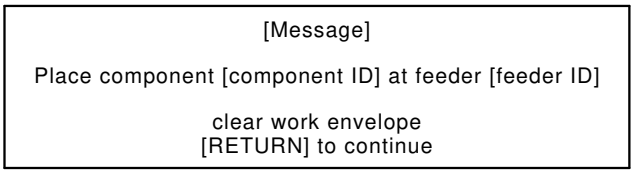
Select the camera identification number to be used for component correction. A list of cameras is displayed on the menu.

3. Teach vision image acquiring location:

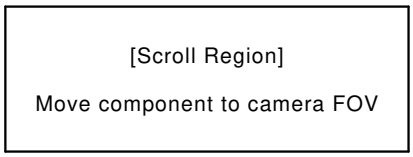
```
set-up - feeder - add ==> [feeder ID] ... * teach vision image
acquiring location

set-up - feeder - modify - [feeder ID] - image loc * teach vision
                                                     image acquiring
                                                     location
```

During assembly, a component is picked from the feeder and moved to the camera where the vision image is acquired and processed. Because component correction is related to the pick-up location, the vision acquiring image location is included in the feeder data base.

To teach the vision image acquiring location. place the appropriate component at the feeder pick-up location. If using an array feeder, place the component at the location closest to the feeder frame center reference dowel pin. The following message appears in the message window:



After placing the component in the feeder pick up location, clear the work envelope and press RETURN. The robot will move to the pick-up location, pick up the component, and pause directly above the pick-up location. The following message appears in the scroll region:



At this time, the selected camera is activated and a live image from the camera is shown on the vision monitor. Use the pendant to move the robot arm until the component is shown on the vision monitor.

For a surface-mount cerquad, the entire component should be captured by the vision system so that the four edges of the component are approximately parallel to the four edges of the monitor. Side 1 of the component, defined as the side where pin 1 is located, should appear on top of the monitor. Press COMP/PWR and REC/DONE to record the location. The following message will appear in the message window:

```
[Message]
Do you want to adjust image quality?
```

NOTE

The image acquiring location does not require z-height adjustment since this information is extracted from the camera data base. Refer to Section 5.3.

A binary image of the component will appear on the vision monitor. Inspect the image to ensure that the image clearly shows all details of the component. Select "yes" from the menu to adjust the image quality if required. Otherwise, select "no" to bypass image quality adjustment. Refer to Section 4.5.

After the image quality is set, the rulers on the vision monitor will migrate from the edges of the monitor until they cut the leads of the component on the image. Location teaching is complete when the following message appears in the message window:

```
[Message]
do you need to re–enter data?
```

Select "yes" from the menu to change component correction set-up data, otherwise, select "no" to end the component correction set-up process. Remove the component from the end-effector.

4. Adjust image quality:

```
set–up – feeder – add ==> [feeder ID] ... * adjust image quality

set–up – feeder – modify – [feeder ID] – adj image quality * adjust
image quality
```

During assembly, a component is picked from the feeder and moved to the camera where the vision image is acquired and processed. Because component correction is related to the pick-up location, the vision acquiring image location is included in the feeder data base.

To adjust the vision image quality, place the appropriate component at the feeder pick-up location. If using an array feeder, place the component at the location closest to the feeder frame origin reference dowel pin. The following message appears in the message window:

```
[Message]

Place component [component ID] at feeder [feeder ID]

clear work envelope
[RETURN] to continue
```

After placing the component in the feeder pick up location, clear the work envelope and press RETURN. The robot will move to the pick-up location, pick up the component, and move to the image acquiring location directly above the camera.

At this time, the selected camera is activated and a live image from the camera appears on the vision monitor.

Use the pendant to adjust the image in binary mode until the image clearly shows all details of the component.

After the image quality is set, the rulers on the vision monitor will migrate from the edges of the monitor until they pass over the images of the leads of the component on the monitor.

5.9 PLACEMENT DATA BASE

Placement data includes basic locations, local error correction data, and component correction calibration data. Placement data can be added, copied, deleted, modified, and listed by selecting "placement" from the set-up menu. Figure 5–11 shows the placement data base menu.

Figure 5–11: Placement Data Base Menu

(Add Menu)

```
[Menu]

exit
add
copy
delete
modify
list
zero
```

(Modify Menu)

```
[Menu]

exit
name
appro ht
# path loc
LocErrCorr
calibration
clinch
place location
```

Placement information includes:

- Name — Alphanumeric identifier for the placement
- Approach height — Distance between the component placement location and the robot arm before and after component placement
- Clear path — Path through which the robot arm moves to avoid obstacles before placing the component
- Local Error Correction — Contains all the information required to perform local error correction

- Calibration — Component correction calibration data
- Clincher — Not implemented
- Placement location — Location where the component is placed on the PWB

The procedure for adding to or modifying the placement data base is described in Section 5.9.1 through Section 5.9.6.

5.9.1 Placement Name

```
set-up - placement - add ==>  [placement name]
set-up - placement - modify - name ==> [placement name]
```

Identify the placement name with a 10 to 12 character alphanumeric string. for example, the placement name "e10" can be used to represent a 64-pin 0.050-inch pitch cerquad placement.

5.9.2 Approach Height

```
set-up - placement - add ... ==> [approach height]

set-up - placement - modify - [placement name] - appro ht ==>
[approach height]
```

The placement approach height (mm) defines the location where the robot arm pauses before placing a component onto the PWB. This location is directly above the component placement location. The placement approach height must be greater than or equal to the component grip height offset. Refer to Section 5.6.5 for further information.

5.9.3 Number of Clear Path Locations

```
set-up - placement - add ... ==> [# path locations]
set-up - placement - modify - # path loc ==> [# path locations]
```

The clear path locations are the point locations through which the robot arm moves when placing a component. It provides an obstacle-free path for the robot.

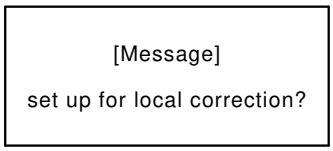
Enter a positive integer if the clear location is required. MAM prompts the user to teach the location(s) that define the clear path. The robot arm will move through the location(s) in the same sequence as the locations are taught. The robot path does not "break" along the clear path. Refer to the *Adept Manipulator System Basic Operation Manual* for details. Enter "0" if the clear path location is not required.

5.9.4 Vision Local Error Correction

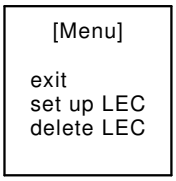
```
set-up - placement - add ... * set up LocErrCorr
set-up - placement - modify - LocErrCorr * set up LocErrCorr
```

Local fiducials are required for placing high pin-count fine pitch components. To set up the local error correction, the known good fiducial locations must be taught using the arm-mount camera or scanner. These fiducial location must be taught using the same PWB from which the component is calibrated for component correction. Refer to Section 5.9.6 for information on component correction calibration.

To add new placement information to the data base, select "yes" from the menu when the following message appears:

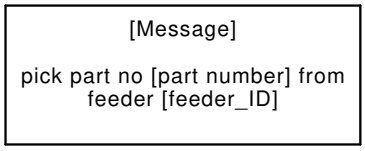


If modifying placement information from the existing data base, select "set up LEC" from the following menu:



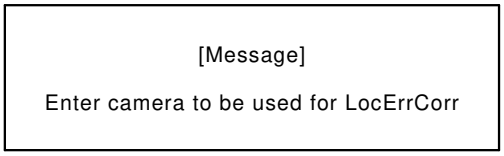
The following steps are required to complete LEC setup:

1. Search part number and feeder for the placement. MAM searches the data base and displays the part number and feeder associated with the placement in the message window, as shown below:

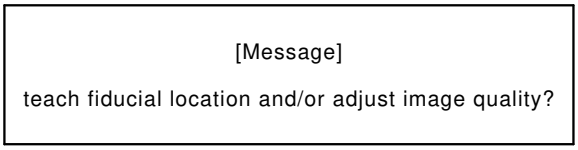


   Select "yes" from the menu if the part number and feeder name are correct. Select "no" to continue the data base search. If the data base does not contain a process that points the correct part number and feeder to this placement process, the part number and feeder must be selected from the menu.

2. Select the camera to be used for local error correction from the menu. The following message appears in the message window:

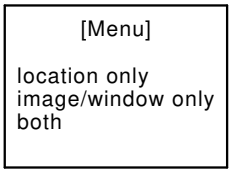


3. Define local error correction parameters — If local error correction parameters do not exist in the current placement data base, MAM prompts for all new locations and data. The following message appears:



Select "no" to use previously defined fiducial parameters, image, and location. If these parameters are not defined in the data base, the message will re-appear in the message window.

Select "yes" to define new fiducial parameters and/or location and image information. The following options appear on the menu:



The user can teach the fiducial locations, adjust the vision image quality, or both. If "location" is selected, the robot arm must be moved to the location where the image is to be acquired. The vision window utility is then used to define the fiducial location. Refer to Section 4.4 for instructions.

If "image" is selected, clear the work envelope and the robot arm will move to the previously defined image acquiring location. The image quality utility is then used for image adjustment. Refer to Section 4.5 for instructions.

If "both" is selected, the new image acquiring location must be taught and the image quality must be adjusted.

The next menu defines which fiducials will be affected:

Select "all" to re-teach all three fiducial locations. Select "first", "second" or "third" to re-teach any one of the three board fiducials.

After the selection, the binary image of the assigned camera is shown on the vision monitor.

Adjust the image quality of the camera using the image quality utility, as described in Section 4.5.

Teach the location of the fiducial using the vision window set-up utility, as described in Section 4.4.

When "first", "second" or "third" is selected, the robot arm moves to the previously defined location for the selected fiducial.

5.9.5 Teach Placement Location

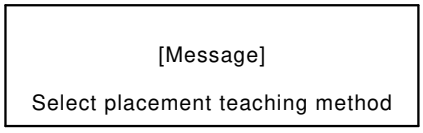
```
set-up - placement - add ... * teach placement
set-up - placement - modify - [place location] * teach placement
```

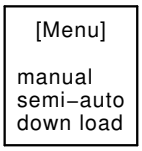
There are two methods for teaching placement locations, semi-auto or manual.

NOTE

Semi-auto placement teaching can only be used if the arm-mount camera is calibrated with "fifth axis patching". Refer to Section 5.1.5.1.

Select the desired placement teaching method when the following message and menu appear:





The following steps are used to manually teach placement locations.

1. Select "manual" from the menu.
2. Place the appropriate part in the feeder.
3. Press RETURN to continue. The robot will pick up the part from the feeder at the (1,1) location and pause over the pick location.
4. Teach the part placement location using the location teaching utility as described in Section 4.3.

Semi-automatic placement teaching uses the camera to locate the two diagonal fiducials on the PWB. The following steps are used to semi-automatically teach placement locations.

1. Select "semi-auto" from the menu.
2. Enter the identification number of the camera to be used for acquiring the fiducial image.
3. Move the robot arm until one of the diagonal fiducials appears at the approximate center of the camera's FOV. The following message will appear:

```
[Scroll Region]

Move arm until diagonal fiducial 1 is at center of camera FOV
```

4. Adjust the image quality if desired using the image quality utility. Refer to Section 4.5.
5. Use the vision window utility to enclose the first diagonal fiducial within a vision window. Refer to Section 4.4.
6. Repeat steps 3, 4 and 5 to acquire the image of the fiducial in the corner diagonally opposite the first fiducial.
7. Enter the placement angle of the component by deviation from the diagonal vector using the right hand rule. The reference of the placement image is based on the vector pointing from fiducial number "2" to fiducial number "1". The reference of the placement angle is based on the vector pointing from the centroid of the lead frame to the midpoint of side 1. See Figure 5–12.

Figure 5–12: Placement Angle

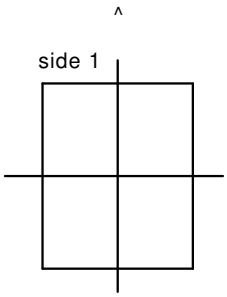
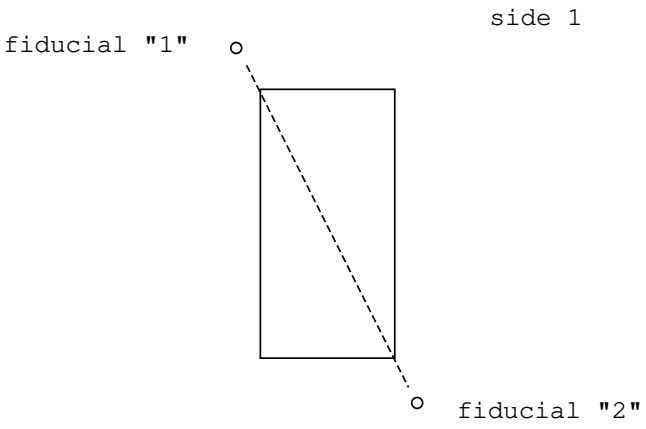


Figure 5–13 shows that side 1 is pointing up and that the deviation from the diagonal vector is at 45 degrees.

Figure 5–13: Deviation from the Diagonal Vector



5.9.6 Component Correction Calibration

```
set-up – placement – add ... * CompCorr Calibration

set-up – placement – modify – [placement ID] – calibration
* CompCorr Calibration
```

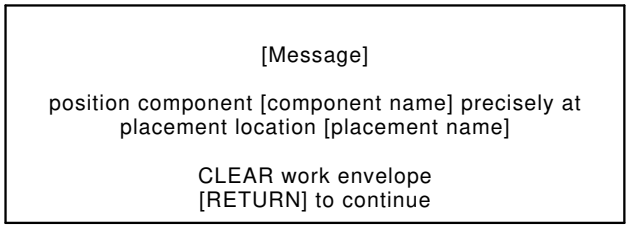
The purpose of the component correction calibration is to establish good reference parameters. Corrections are made for future placements to match these parameters to ensure accurate placement.

If "semi-auto" placement teaching method is used, the calibration procedure is optional since this reference is established mathematically during placement location teaching.

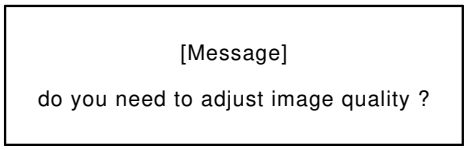
Before the component correction calibration, at least one process that contains information related to the current placement must be defined in the process data base. If this relationship is not defined, the following message will appear:

```
[Message]

component & feeder not defined in previous process
[RETURN] to continue
```

If the process data base does contain the necessary process data, the following message will appear:


[Message]
position component [component name] precisely at placement location [placement name]
CLEAR work envelope
[RETURN] to continue

Ensure that the component type is correctly displayed as "component name" in above message before placing the component at the appropriate placement location. Clear the work envelope and press RETURN. The robot will approach the placement location, pick up the component from the PWB and move to the table-mount camera. The table-mount camera should be activated at this time and the image of the component should appear on the vision monitor.



Select "yes" from the menu to invoke the image quality utility. Refer to Section 4.5. When an acceptable image quality is obtained, "rulers" will be seen in four edges of the monitor starting from the top of the vision monitor and proceeding clockwise. This is consistent with the four sides of the component numbering convention: that is, the top is side 1, and side 2 is on the left side of the vision monitor.

When you complete the calibration, remove the component from the end-effector.

5.9.7 Placement Download

When the download option is selected, the user is prompted to enter the "x", "y", and angular placement locations. The "x" and "y" coordinates used for placement location should be the same as the coordinal system used for the board fiducials.

1. Select "download."
2. Enter the "x" coordinate of the component centroid.
3. Enter the "y" coordinate of the component centroid.
4. Enter the angle of the component.

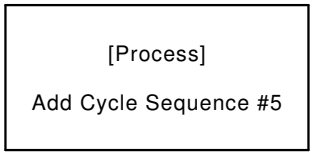
5.10 SEQUENCE DATA BASE

The sequence data base controls the sequential order of the pick-and-place processes defined in the process data bases. Use the following menu sequence to add a new sequence to the data base. Previously defined process numbers (from the process data base) appear in the menu window after you select "add" from the maintenance menu.

```
set-up - sequence - add - [process_ID]
```

MAM assigns sequence identification numbers internally. Sequence data can be added, deleted, or listed after selecting "sequence" from the set-up menu.

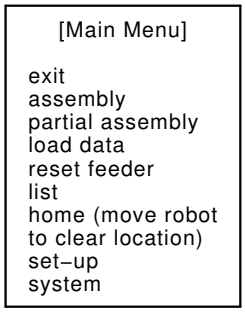
When you add a new sequence to the data base, the current sequence number appears in the process window. For example, if four sequences have been defined, the next sequence added to the data base will be sequence #5. The following message appears in the process menu after selecting "add" from the maintenance menu:



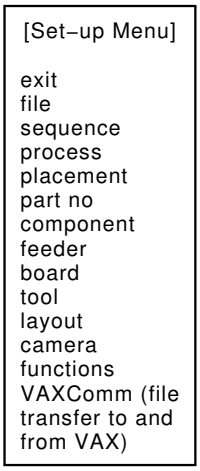
The previously defined pick-and-place processes appears in the menu. Select the appropriate process from the menu to complete the sequence adding procedure.

When you select "assembly" from the main menu, the processes will be executed according to the sequence defined in the sequence data base.

APPENDIX A MENUS

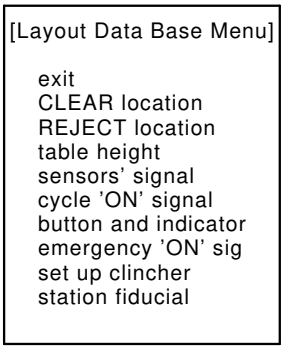


Main Menu

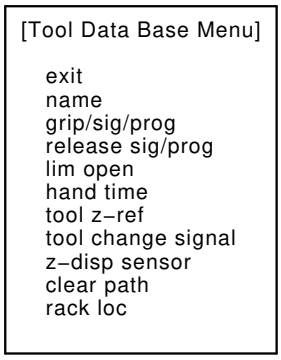


Set–up Menu

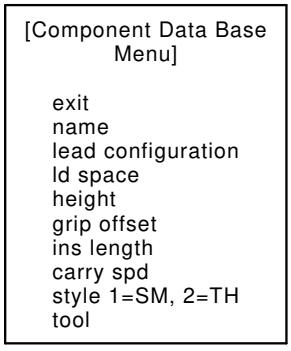
Maintenance Menu



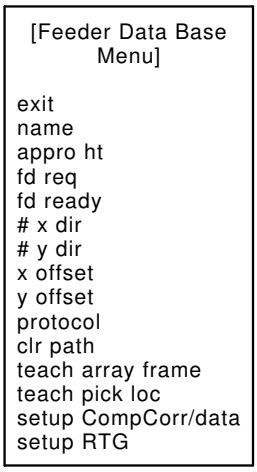
Layout Data Base Menu



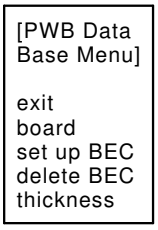
Tool Data Base Menu



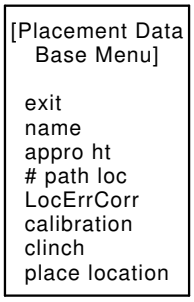
Component Data Base Menu



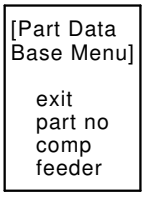
Feeder Data Base Menu



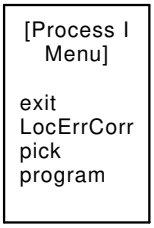
Printed–Wiring Board (PWB) Data Base Menu



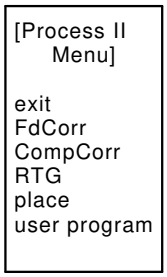
Placement Data Base Menu



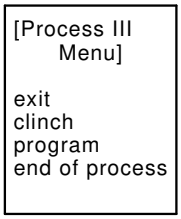
Part Data Base Menu



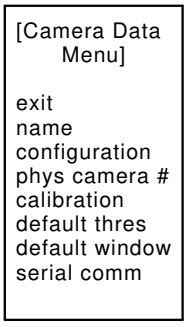
Process I Menu



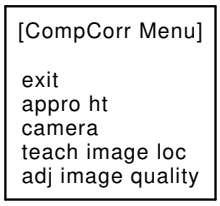
Process II Menu



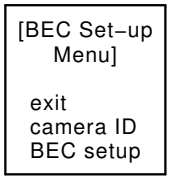
Process III Menu



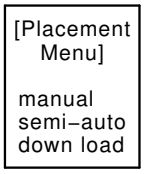
Camera Data Base Menu



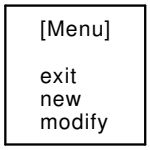
Component Correction Menu

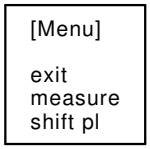


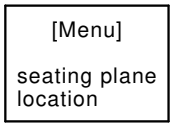
BEC Set–up Menu

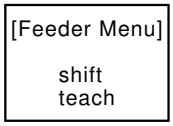


Placement Menu


[Menu]
exit
new
modify


[Menu]
exit
measure
shift pl


[Menu]
seating plane
location


[Feeder Menu]
shift
teach

APPENDIX B MAM PROGRAM VARIABLES

B.1 OVERALL STRUCTURE

MAM is a large data base with pointers directing the user from one data base to another. These pointers piece together the information in different data bases to construct a usable assembly process. The pointers are actually indices of array variables within the program. The following headings describe these indices and variables.

B.2 VARIABLES

B.2.1 Indices

i_ca - currently running camera
i_co - currently running component
i_fd - currently running feeder
i_pa - currently running part number
i_pl - currently running placement
i_pr - currently running process
i_se - currently running sequence
i_to - currently running tool

B.2.2 Workstation Layout Variables

Location Variables:

Clear - robot resting location
Reject - reject component reject location

Real and String Variables:

pps - part present sensor input signal number
sig_pnp[ ] - output signal number to be turned on at pick and place
$sig_pnp[ ] - description of above signal
st - START button input signal number
home - HOME button input signal number
tm - TERMINAL button input signal number
reset - RESET button input signal number
bypass - safety bypass switch input signal number
em_lt - emergency button light output signal number
fc_lt - function button light output signal number
sig_em[ ] - output signal number to be turned on at emergency
$sig_em[ ] - description of above signal

B.2.3 Feeder Variables

Location Variables:

waf[ ]- feeder frame
pick[ ] - feeder pick up point x, y location (z = fdzr[ ])
fd_cl[,] - feeder clear path point location (first index: feeder pointer, second index: points' number)
fd_cc[ ] - component image acquiring location during component correction

Real and String Variables:

fd_bm[ ] - feeder bit mask
fd_tot - total number of feeder in data base
$fd_id[ ] - feeder name
fd_ht[ ] - approach height
$fd_rq[ ] - feeder request signal/program
fd_rd[ ] - feeder ready signal/program
wxtot[ ] - feeder matrix array size in 'x' direction
wytot[ ] - feeder matrix array size in 'y' direction
wxoff[ ] - feeder matrix array offset in 'x' direction
wyoff[ ] - feeder matrix array offset in 'y' direction
fd_zr[ ] - feeder z-reference height
fd_cl[ ] - number of feeder clear path points
fd_cx[ ] - 'x' coordinate on vision system to define ruler window for component correction
fd_cy[ ] - 'y' coordinate on vision system to define ruler window for component correction
fd_cw[ ] - size of vision ruler window for component correction
fd_cht[ ] - approach height to camera
fd_cid[ ] - camera to be used for component correction image acquisition
fd_ga[ ] - component correction image gain setting
fd_th[ ] - component correction image threshold setting
fd_of[ ] - component correction image offset setting
fd_lu[ ] - logical unit number to communicate to feeder, defaulted to "9."

B.2.4 Part Number Variables

pa_tot - total number of part number in data base
pa_bm[ ] - part number bit mask
$pa_id[ ] - part number
pa_cid[ ] - pointer to component identity
pa_fid[ ] - pointer to feeder identity

B.2.5 Placement Variables

Location Variables:

pl_tot - total number of placement in data base
pl_cl[,] - number of placement clear path points (first index: placement pointer, second index: points' number)
place[ ] - placement 'x' 'y' location
pl_cf[,] - local error correction image acquiring locations (first index: placement identification, second index: fiducial identification)

Real and String Variables:

pl_bm[ ] - placement bit mask
pl_th[ ] - placement approach height
pl_cl[ ] - number of clear path points
pl_fc[ ] - camera used for local error correction
pl_th[,] - local error correction threshold setting (first index: placement identification, second index: fiducial identification)
pl_ga[,] - local error correction gain setting (first index: placement identification, second index: fiducial identification)
pl_of[,] - local error correction offset setting (first index: placement identification, second index: fiducial identification)
pl_cfx[,] - calibrated 'x' coordinate of local fiducial (first index: placement identification, second index: fiducial identification)
pl_cfy[,] - calibrated 'y' coordinate of local fiducial (first index: placement identification, second index: fiducial identification)
pl_wx[,] - 'x' coordinate on vision system to define image acquiring window (first index: placement identification, second index: fiducial identification)
pl_wy[,] - 'y' coordinate on vision system to define image acquiring window (first index: placement identification, second index: fiducial identification)
pl_ww[,] - size of vision window (first index: placement identification, second index: fiducial identification)
xcal[ ] - calibrated 'x' location of component correction location
ycal[ ] - calibrated 'y' location of component correction location
xoff - 'x' location of component correction location of current board
yoff - 'y' location of component correction location of current board

B.2.6 Process Variables

pr_tot - total number of processes in data base
pr_bm[ ] - process bit mask
pr_st[ ] - process step counter
$pr_st[,] - process step description (first index: process identification, second index: step counter index)
pr_prog[ ] - process subprogram counter
$pr_prog[,] - process subprogram name (first index: process identification, second index: program counter index)
$pr_id[ ] - process identification

B.2.7 Tool Variables

Location Variables:

to_rk[ ] - tool rack location
to_ap[ ] - tool rack approach location

Real and String Variables:

to_tot - total number of tool in data base
to_zr[ ] - tool z-reference height
$to_gr[ ] - grip signal/number
$to_re[ ] - release signal/number

to_lo[ ] - parallel gripper limit opening option signal number
to_hd[ ] - hand time
$to_id[ ] - tool description

B.2.8 Board Variables

Location Variables:

bo_cf[ ] - board error correction image acquiring locations (index: fiducial number)

Real and String Variables:

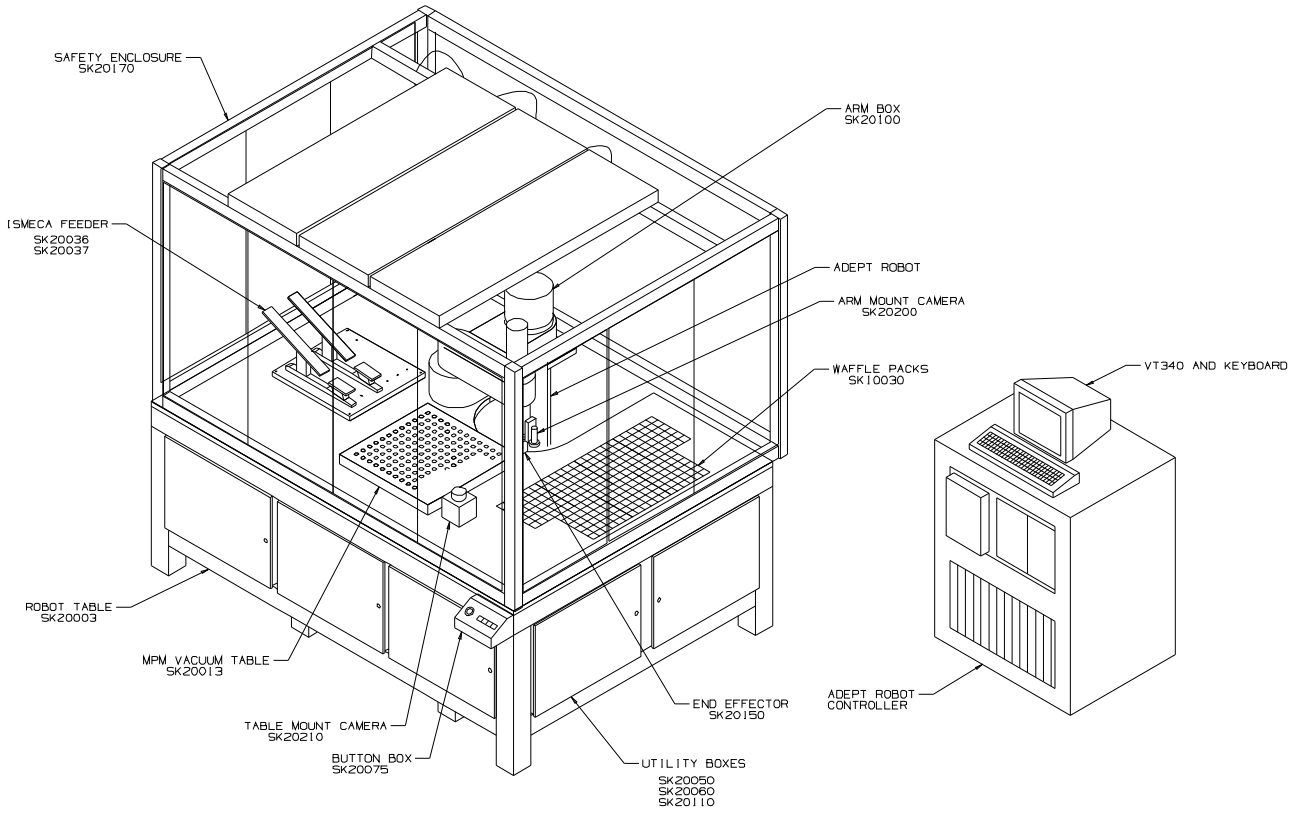
$bname - board (module) name
bo_rdy - board flag
bo_zr - board thickness z-reference
bo_fc - camera identification for board error correction
bo_ga[ ] - vision gain setting for board fiducials
bo_th[ ] - vision threshold setting for board fiducials
bo_of[ ] - vision offset setting for board fiducials
cbx_fu[ ] - calibrated 'x' coordinate of fiducial location
cby_fu[ ] - calibrated 'y' coordinate of fiducial location
bx_fu[ ] - 'x' coordinate of fiducial location of current board
by_fu[ ] - 'y' coordinate of fiducial location of current board

B.2.9 Component Variables

co_bm[ ] - component flag
co_lc[,] - component lead count (first index: component identification, second index: side)
co_ls[ ] - component lead spacing
co_ht[ ] - component height
co_os[ ] - component grip offset
co_sp[ ] - component carrying speed
co_st[ ] - component style
co_toid[ ] - component tool identification

APPENDIX C GENERAL ROBOTIC WORKSTATION

Figure C–1: Generic Robotic Workstation



APPENDIX D REFERENCE DOCUMENTS

D.1 EL-Class Digital Documents

EL-Class Number	Document Title
EL-MF519-00	*Acceptance Specification for the Generic Robotic Workstation*
EL-MF519-01	*Generic Robotic Workstation Operator's Guide*

Use VTX SMC to order copies of EL-class documents from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

D.2 Ordering Information

Following is the source for documents not available from Standards and Methods Control.

Adept Technology, Inc.
150 Rose Orchard Way
San Jose, CA 95134
Telephone: (408) 432-0888

GLOSSARY

The following definitions explain the terms used in this document.

Adept One robot controller: The central processing unit (CPU) for controlling the robot motion and its communication with other control mechanisms. The Adept One Robot Controller is used with the Generic Robotic Workstation.

Adept One robot manipulator: The Adept One Robotic Manipulator System, also referred to as the robot arm. Information on the Adept robot and its controller can be obtained from Adept Technology, Inc., 150 Rose Orchard Way, San Jose, CA 95134. Telephone: (408) 432-0888.

approach height: The position directly above the feeder where the robot manipulator momentarily halts both before and after a component is picked from a feeder. This parameter defines a path to eliminate collisions between the robot manipulator and the peripheral equipment installed in the work envelope.

button box: Used for external control during daily operation. It has one emergency stop push button (panic button), a START keyswitch, and three momentary push buttons. The three momentary push buttons are HOME, TERM, and RESET. All push buttons are equipped with an indicator light.

carrying speed: The speed of the robot arm while carrying a component on the end-effector.

clear path: The locations through which the robot arm moves to avoid obstacles before placing a component.

clear position: The position where the robot arm resides when not performing pick-and-place. The robot arm must be in this position at the start and end of a pick-and-place cycle.

compliant wrist: A mechanical interface between the end-effector and the robot manipulator. It is spring-loaded and unconstrained in the insertion/onsertion z-direction.

component correction: Corrects positional errors. The component is picked up by the robot arm and inspected by the vision system or scanner to determine its exact location.

component height: The dimension from the component seating plane on which the leads rest to the top surface of the component.

component style: Either surface-mount or through-hole.

emergency signals: Signals to be turn on/off during emergency interrupt.

end-effectors: Mechanisms installed on the end of the robot manipulator to allow the robot to perform various functions. A suction type gripper is used for surface-mount components; a parallel jaw gripper is used for nonstandard through-hole components.

feeders: Mechanisms for supplying components to the robot for module assembly. The feeders supported by MAM are independently controlled. The two types of component feeding arrangements are:

> **point feeder -** A component feeder that feeds components to a single repeatable location to be picked up by the end-effector. The two types of point feeders used with the workstation are vibrational "ski slope" feeders and tape feeders.
> **wafflepack or matrix tray -** A flat metal plate with "pockets" that resemble the pattern on a waffle. The "pockets" have equal center-to-center distances and components are placed tightly inside.

grip height offset: Dimension determining the "depth" of the grip for parallel gripper.

gripper displacement sensor (GDS): A force sensor installed on the end-effector that detects motion in the insertion/onsertion z-direction. This sensor is used to prevent excessive force during insertion/onsertion.

grip signal/program: Signal or subroutine program to activate the grip action of the end-effector.

indicator and buttons: Signals for the indicators and buttons used for interfacing with operators.

input/output (I/O) signals: Input/output referencing to the robot controller.

lead count: The number of leads on each side of a component.

lead spacing: The distance between the center lines of two adjacent leads.

limit opening: Signal to limit the opening action of the parallel gripper.

module assembly data: Data that defines all parameters associated with a particular type of module. This data is different for each module type.

part present sensor (PPS): A sensor installed on the end-effector that detects the presence of components on the end-effector.

pendant: A remote control panel or device used for robot motion control. Refer to the *Adept Manipulator System Basic Operation Manual* for further information.

peripheral equipment: All support hardware for the workstation, including vision systems and feeders.

pick location: Includes the feeder seating plane height on which the lead of the component rests and the x-y location of the pick up location.

printed-wiring board (PWB) mounting fixture: A suction-type table top used to minimize PWB warpage of surface-mount modules during operation of the workstation.

process signals: Signals to be turned on during a pick-and-place process cycle. For example, the warning light.

reject location: Location where rejected parts are dropped.

release signal/program: Signal or subroutine program to activate the release action of the end-effector.

safety devices: Physical or non-physical barriers used for preventing physical contact with the robot during operation. A safety enclosure surrounds the work envelope. Any violation of this enclosure automatically halts robot motion.

scanner: A multi-purpose reflective laser sensor used for tasks such as component inspection and placement error correction.

thickness: The thickness of the printed-wiring board.

tool: The tool on the end-effector to be used for component picking.

work envelope: The total area accessible to the robot.

workstation layout data: Data that defines all parameters associated with the workstation including feeder and scanner locations. Minor modifications to these parameters may be required for different module types, but most parameters remain unchanged within the same workstation.

work table: The mounting platform for the robot and all required accessories.

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